Liro Forestry Solutions

PROJECT REPORT

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# IMPROVED LOG TRAILER DESIGN

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Leading Edge Forestry Solutions

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# Improved Logging Trailer Design Project


## Summary

Transport Technology has been commissioned to undertake a design project, investigating alternatives to existing 3 and 4 axle logging trailer shorts. From previous investigations it has been found that there is a serious problem with the amount of trailer logging trailer rollovers in New Zealand due to poor stability.

Designs are restricted by many different parameters and it was found that there are many alterations to existing designs that will improve the stability, however to get significant improvements within the parameters the task is a lot more difficult.

Lowering the centre of gravity has been pinpointed as the best method to get large improvements in stability. Clearance around the gooseneck area in the trailer is minimal and so a perimeter frame trailer has been designed. For three axle trailers there has been on average a 10% improvement on stability, however the four axle trailer is not as successful. Load distribution is uneven for carrying short logs causing stability to be worse. If the 4 axle trailer was only to be used for long logs, improvement in stability again of 10% is apparent.

It is recommended that a 3 axle perimeter frame design be put to the test. For 4 axle trailers it is possible to lower the centre of gravity a small amount without the perimeter frame, and so this option could be feasible. If legislation would allow some of the parameters to change, then it is possible to improve stability even further.

# Acknowledgements

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*Liro Limited*

*Kraft Engineering*

*Patchell Industries*

*Evans Engineering*

*Transport Efficiency*

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Transport & Mechanical Design Engineers

## CONTENTS

# 1.0 INTRODUCTION

## 1.1 BACKGROUND

On going concern over the number of logging vehicles that have rolled over in recent years. In order to try and reduce this problem LIRA has commissioned Transport Technology LTD to undertake investigations into the design, and re-design of the logging rigs.

A logging truck stability analysis done by the Transport Engineering Research New Zealand (TERNZ) has revealed that a large proportion of rollovers happened on truck – shorts trailer combinations carrying 3.7m and 4.1m logs. Due to this, 3 and 4 axle trailer shorts will be the object of our studies. Results of this study suggested that poor stability and maintenance are major factors in logging truck crashes.

A analysis has been undertaken on the design and stability of three and four axle short logging trailers. This will give a bases for any decisions which will be made to improve the number of rollover accidents occurring on New Zealand roads.

## 1.2 OBJECTIVES

To investigate alternative trailer designs in an effort to improve stability, and in doing this increase safety and achievable payloads within the current legislative framework.

## 1.3 PROCEDURE

So that the objectives are reached effectively, a set procedure will be followed. From this procedure, decisions can be made based upon conclusions and results. The procedure is as follows:-

1. Define problem objective
2. Find out any parameters related to the problem.
3. Study the existing trailer designs.
4. Redesign of the current 3 and 4 axle trailer shorts
5. Design of alternate trailers that can adequately do the job.
6. Stability analysis.
7. Feasibility of the various solutions.

# 2.0 METHODOLOGY

## 2.1 PARAMETERS

Trailer designs are currently dictated by physical and legislative restrictions. In all the alternatives to the current trailer design considered, these have to be adhered to. Parameters described below have been summarised in a general layout drawing of a full logging shorts trailer, which can be seen in Appendix 1.

These parameters have be divided into 3 sections: legal, operating, and physical parameters. Additional parameters have also been introduced, which are not mandatory for the trailer design, they have proven to be successful in the industry.

### 2.1.1 LEGAL PARAMETERS

- Width: <=2.5 metres
- Height: <=4.25 metres
- Trailer overhang: <=3.2m or 60% of the trailer wheelbase.
- Truck rear overhang: <= 3.2m / 3.7 m or 60% of the trailer wheelbase.
  (ROH can be 65% or 70% with 20 meter permit)
- Gross and axle weights limited to legal highway limits.

### 2.1.2 OPERATING PARAMETERS

- Provide a window 200mm deep by 3200mm long as stacker access for loading and unloading of logs.
- The trailer dolly must be able to rotate 180 degrees when piggybacking trailer on truck.
- The length of the trailer must be such so that when it is being piggy backed, the legal rear overhang limit of the truck is not exceeded.
- Carry logs whose length ranges from 3.7m to 8.2m

### 2.1.3 PHYSICAL PARAMETERS

- Tyre and guard clearance with gooseneck.
- Clearance between the truck and trailer for turning.
- It has been calculated that for the mono spring leaf suspension system, under a maximum load of 7000kg per axle, a deflection of 25mm is incurred. This is while the trailer is loaded and stationary. It is expected however that this will as much as double if the trailer was to be going around a corner and hitting a bump at the same time. In new trailer designs, the minimum tyre clearance should be 60mm.

### 2.1.4 INDUSTRY PARAMETERS

- The stanchion thickness is taken to be 130mm
- Stanchion height is 1800mm with removable extension pins.

## 2.2 DATA

Requests for information to do with trailer design and componentry were sent to three main logging trailer manufacturers and 4 main componentry suppliers. In response to these we have received information back and spoken to knowledgeable people in these industries.

A spread sheet has been constructed to calculate centres of gravity's and axle loads for calculations in the stability analysis. An example of the spreadsheet can be seen in appendix 2. There are many slight variations on the current 3 and 4 axle logging shorts. Analysis cannot be done on all of them and so control trailers have been made to represent this group. Stability of these will be analysed and used to compare with any new designs.

### 2.2.1 LOADS

The log loads are to be applied to the trailer in the form of a uniformly distributed load across the top of the two bolsters. Logs of lengths 3.7, 4.1, 5.8, 7.4 and 8.2m will be used in calculations. The volume of logs in each load is based upon a stacking ratio. This ratio is an indication of a rectangular cross section of load, based on the load width and height, how much of it is filled with wood and how much is air. For the purposes of this project the maximum allowable dimensions for height and width of the trailer are at their legal limits. The width of the load is equal to the maximum permissible trailer width less the thickness of the stanchions. The load height is equal to the required height of the load so that maximum payload is reached, unless the legal height restriction is broken, in which case the payload is reduced and the height becomes the maximum legal height.

### 2.2.2 WEIGHTS

The gross vehicle masses used for the trailers are 21,500 kg for 3 axle trailer shorts and 22500 kg for 4 axle trailer shorts. These maximum weights were kept the same for all the designs, so that accurate comparisons could be made.

### 2.2.3 CONTROL TRUCK

In the stability analysis a truck is required for the software to work. What has been used here is a 3 axle truck running on a spring leaf suspension system, whose axle weights and dimensions have been taken from the TERNZ report.

## 2.3 CONTROL TRAILERS

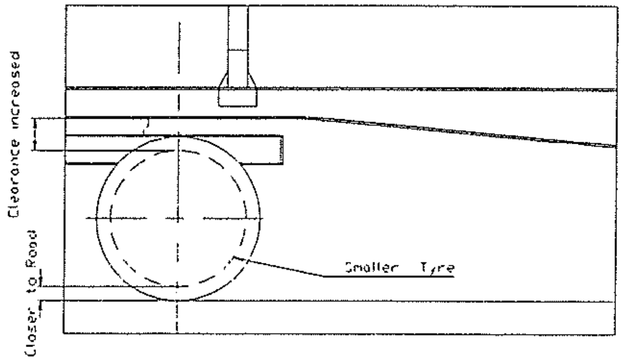
The objective of this project has been defined as improving the current trailer designs. For improvements to be physically shown, new designs have to be compared to an existing one. Information from componentry specialists, and trailer manufacturers has been used to draw up three and four axle control trailers (see appendix). The trailers' running gear is made up of a monoleaf suspension system operating with 265/70 R19.5 tyres. Both the control trailers have been drawn up in the Appendix 3.

## 3.0 TRAILER DESIGNS AND SUITABILITY

The components and parameter limitations have been reviewed in this section and various trailer modifications considered to determine their contribution to the project objective. There are many alterations which can be made to the trailer including componet and structural changes however not all result in sufficient nett benefit to whole vehicle The feasibility and suitability of each option is looked at to determine the best solution.

### 3.1 TYRES

By using smaller tyres the whole trailer frame is lowered. Also because of the decrease in radius of the tyres, there will be more clearance at the restricted areas meaning that small changes might be able to be made to the trailer frame to lower it even more.




FIGURE(3.1.1):Effect that tyre change has on trailer geometry

ADVANTAGES:
The trailer is lowered making it more stable.
Price wise, it is a cost effective method of improving the trailer design.

DISADVANTAGES:
Using smaller tyres would mean that the tyres wear quicker causing new tyres to be needed more regularly. This might mean greater costs as well as more time off the road.

### 3.2 SUSPENSION

Currently at use in the logging industry are both air and spring leaf suspension systems. The main difference between the two is in their elastic properties. A spring leaf system has a high spring constant and auxiliary roll stiffness, where as air systems have lower spring constants with higher roll stiffness. Not only can the type of suspension system be modified, but so to can the configuration.

3.2.1 SIDE MOUNTED SUSPENSION

This involves the suspension brackets being mounted on the outer edge of the chassis rails. This gives the facility to space the springs further apart, but also vary the trailer height by moving the mounting brackets up or down the side of the chassis

Advantages:
Lowering the height of the trailer and increasing the spring spacing will improve the stability of the trailer.

Disadvantages:
There are limitations around the gooseneck as to how much the trailer can be lowered. Due to the offset spring mountings there will be additional stress placed on the trailer chassis, possibly requiring it to have more strengthening.

3.2.2. UNDER-SLUNG SUSPENSION

By mounting the suspension springs on the underside of the axle, the trailer can be significantly lowered.

Advantages:
Can be used to lower the trailer height. Due to the axle offset from the suspension mount being smaller than that of conventional systems, there will be less lateral stress on the suspension system.

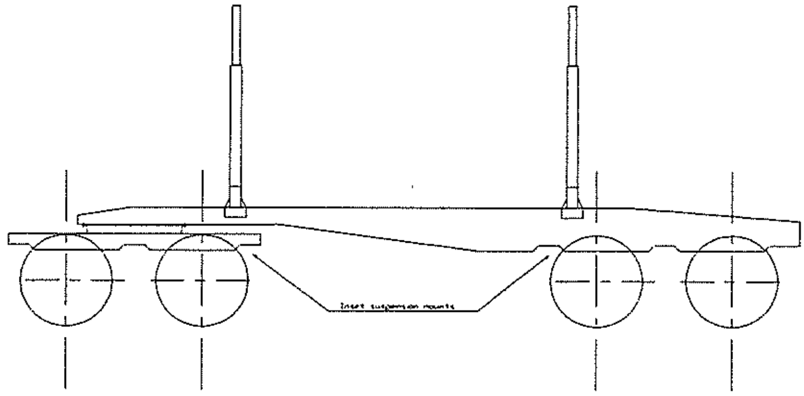
Disadvantages:
The roll centre height will be lowered effecting the stability of the trailer. The trailer can only be lowered by a small amount before the gooseneck will be hit by the tyres. By having underslung suspension this amount may be exceeded. If this is the case then the suspension mounts would have to be packed which is not an appropriate solution as tare weight is increased as well as the trailer height being raised having a negative effect on the stability.

3.2.3 INSET SUSPENSION MOUNTS

By keeping the same frame, the trailer can be lowered by having the suspension mounts inset to the frame. Additional strengthening will be needed through these areas due to the reduction in section depth. Because of the limited space between the gooseneck and tyres the trailer can only be lowered a small amount.

ADVANTAGES:
This will lower the centre of gravity.

DISADVANTAGES:
Can only lower the centre of gravity by a small amount due to clearance at the gooseneck. Due to the geometry of this there will be more stress concentration areas. The time and difficulty of manufacture will be increased. Due to the change in chassis section depth additional strapping will be needed. Additional welding and corner edges produced by the geometry of the change will create new stress concentration areas which in any design is desirable to be kept to a minimum when in high fatigue cycle operations.




FIGURE(3.3.2): Inset suspension mounts

## 3.3 STEERING MECHANISM

The difficulty in lowering the centre of gravity of the current trailer is due to the amount of space required for the dolly to rotate, without hitting the gooseneck area.
Using a different steering mechanism, the ball race could be removed along with the gooseneck, so that you end up with a truck type trailer chassis with a conventional steering system.

ADVANTAGES:
The centre of gravity of the trailer will be lowered due to the removal of the ball race.

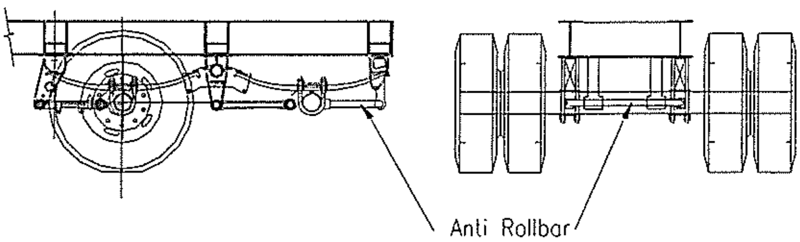
DISADVANTAGES:
Manoeuvrability of the trailer is changed dramatically, going both forwards and backwards.
The angle of turn on the front wheels will be reduced from 90 degrees in the case of a ball race to only about 41 degrees. This greatly reduces the turning circle for a truck trailer set up. When backing with this steering system the steering will reach a maximum and then lock, such that the truck will just push the trailer, dragging the wheels.

## 3.4 ANTI ROLLBAR

An anti-rollbar can be fitted to the axles and the chassis via a series of rubber mounts. This bar acts in torsion providing extra support in the suspension and better handling performance. The bar can be attached at each end of the axle and taken up on an angle to the chassis where it can be mounted

ADVANTAGES:
The auxillary roll stiffness of the suspension system is increased and hence so to will stability. Is a simple modification which can be made to existing trailers.

DISADVANTAGES:
Puchase and fitting costs. Tare weight will also be lost, however in comparison with the weight of air suspensions, will similar if not lighter.




FIGURE(3.4): Anti Rollbar positioning

## 3.5 CONVERT THREE AXLE TRAILERS TO FOUR AXLE

The stability performance of 3 axle trailers is significantly worse than that of 4 axle trailers. A short term suggestion is to convert current 3 axle trailers to 4 axle. The problem with this is that 4 axle trailers being longer will exceed the 60% legal overhang limit whilst being piggy backed. Permits could be issued for a given time period so that the rear overhang may be exceeded until the operator's truck is replaced. This means many operators will be able to introduce 4 axle trailers without a huge expense. Similar permits have been issued in the past for over height containers. Where a two and a half year permit could be used to carry 2.9m high containers instead of the standard 2.6m.

ADVANTAGES:
There will be less 3 axle trailers around, hence an overall improvement in the number of trailer rollovers. Four axle trailers can be double bunked and will have lower loads.

DISADVANTAGES:
The rig will be longer. Larger tare weights.

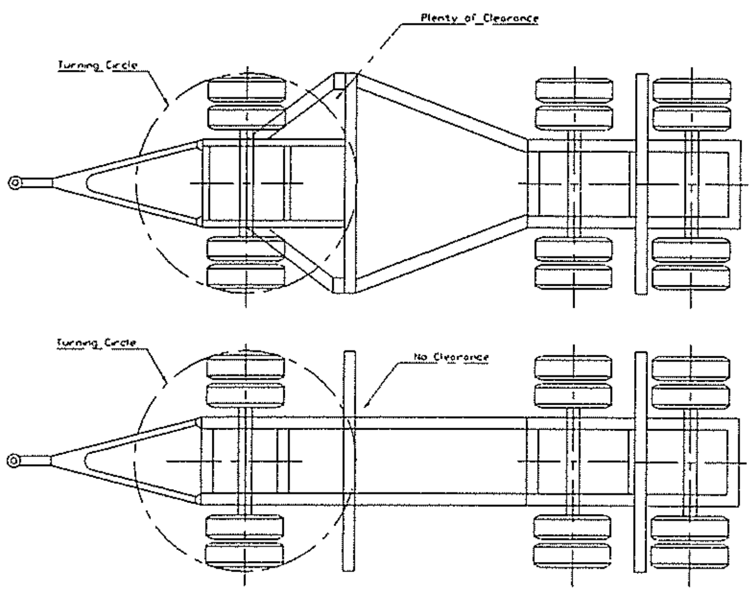
## 3.6 NEW FRAMES

### 3.6.1 PERIMETER FRAME

It is required in the parameters that over a distance of 3200mm between the bolsters there is a 200mm gap between the top of the trailer and the base of the load. At present the bolsters sit on top of the trailer chassis rails, however if they where to be made part of the frame then the load height could be lowered by 200mm. The current trailer design has very limited space around the gooseneck area and if the bolsters where to be inset and the trailer kept how it was then for the trailer to handle the loads the required amounts of material would mean that the dolly would hit the gooseneck. This problem is solved by using a perimeter frame. At the edges of the trailer the turning circle of the dolly does not go as far back which means that the gooseneck area is not as strictly restrained.

In the case of the three axle trailer, the bolster positions can remain at the same longitudinal positions along the trailer length. However for the 4 axle design, because there are two axles, the front bolster is overtop of the rear dolly axle. This means that when the bolster is lowered, a perimeter frame cannot be used as the tyres are in the way. For the 200mm deep space to be achieved between the bolsters for loading

and unloading means that the bolster has to be moved back some 400mm so that firstly there is sufficient clearance, and secondly so that there is enough material to hold the trailer together.
Moving the front bolster back means that the rear one has to be moved back as well so that the 3200mm space between the bolsters is kept. For 3.7m and 4.1m logs, because of their length cannot sit forward on the bolsters and have to sit back, moving the centre of loading on the trailer further back.




FIGURE(3.5.1): Advantage of using a perimeter frame

ADVANTAGES:
The cog is lowered increasing stability.
Because there is a perimeter frame the loader when going in to pick up logs can see whether the forks are high enough to miss the trailer and go under the logs. This will hopefully reduce damage that the trailer might experience in loading and unloading situations.

DISADVANTAGES:
More material is needed meaning an increase in the tare weight of the trailer. The difficulty of manufacture is increased due to the geometric shape of the frame. On the four axle trailer, due to the bolsters being moved back, the load centre may to be moved back, affecting the stability of the trailer.

## 3.6.2 INSET BALL RACE

A typical ball race at present is 90mm deep. This means that between the front dolly and the trailer frame there is a 90mm gap. The trailer at this point is very rigid, meaning that the gap between the two could be reduced down to about 20mm. The front can be lower down, and the rear end lowered to suit.

ADVANTAGES:
This will lower the centre of gravity.

DISADVANTAGES:
Can only lower the centre of gravity by a small amount due to clearance at the gooseneck.

### 3.6.3 STRENGTHENED ORIGINAL FRAME

Keeping the same current trailer layout and basic design, the centre of gravity can be lowered through decreasing the depth of some sections and increasing the web thickness and amount of strapping in certain areas.

ADVANTAGES:
The section depth, over the length of the chassis can be reduced a small amount to lower the centre of gravity. Altering the sections depths will change the gooseneck area possibly giving more clearance so that if componentry set up is changed the trailer can be lowered more.

DISADVANTAGES:
Due to decreasing the section depth the trailer will not be as structurally stiff and will flex more. Doing this may require only small changes in section depths meaning that odd section dimensions may be needed, meaning that standard steel sections can't be used. This will increase cost and time as beams have to be fabricated.

## 3.7 CONCLUSION

There are lots of possible options to lowering the COG and increasing stability. It is clear that any single small change in the existing trailer will not achieve much of an improvement due to the clearance restrictions around the gooseneck.

In the case of the 3 axle trailer, a perimeter frame is definitely a large improvement on the old design. It is also possible to combine the perimeter frame with other solutions to make it even lower again.

For the 4 axle trailers, there are two options. The perimeter frame should be used if the trailer is to carry only long loads as this is the area in which it performs well. The other option of decreasing the section depth, insetting the suspension mounts, and possibly by other means, lowering the trailer, proves to be the best all round improved design, given the trailer parameters at the start.

**TRAILER CHANGES SUMMARY**

| CHANGE | STABILITY PERFORMANCE | PRACTICALITY | EFFECTS | COMMENTS |
|---|---|---|---|---|
| TYRES: | Positive | Positive | Small | |
| SUSPENSION: | | | | |
| Side Mounted | Positive | Positive | Small | |
| Under Slung | Negative | Positive | Small | |
| Inset Mounts | Positive | Positive | Small | |
| STEERING MECHANISM | Positive | Negative | Medium | Disregard because manoveabilty is poor |
| ANTI ROLLBAR | Positive | Positive | Small | |
| NEW FRAMES | | | | |
| Perimeter Frame | Positive | Positive | Large | 4 axle trailer performance is not good |
| Inset Ball Race | Positive | Positive | Small | |
| Strengthened Existing Frame | Positive | Positive | Medium | |

# 4.0 STABILITY ANALYSIS

The stability analysis has been carried out on the 3 and 4 axle control trailers, as well as three new designs. The first two are the 3 and 4 axle perimeter framed trailers, and the last is a 4 axle trailer whose load centre of gravity has been lowered some 100mm by decreasing section depth and then strapping of the 4 axle control trailer.

The software used has been done on validated computer software, supplied by the University of Michigan Research Institute (UMTRI). Two simulations will be done. The first is a static roll model which determines a static rollover threshold (SRT), and the second is a dynamic handling model, used to determine the dynamic load threshold ratio. The stability analysis requires many constants and variables to operate. A lot of these dramatically effect stability, and so to see the effect of these changing simulations have been done and trends found.

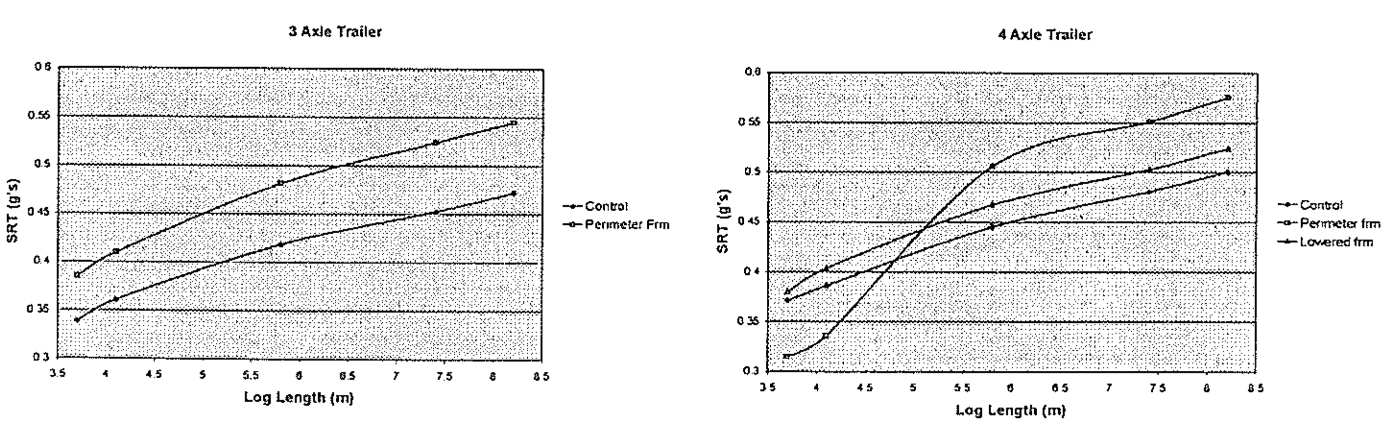
Componentry is an important part of the trailer design and a comparison between air and mono spring leaf suspension systems has also been done.

## 4.1 STATIC ROLL

### 4.1.1 BACKGROUND

The Static Roll Model examines the steady state (constant lateral acceleration) roll response of multiple unit vehicles over the full range of lateral acceleration from zero up to the roll stability limit of the vehicle. The model predicts roll angle response of the vehicle (sprung and un-sprung masses) and the side to side load transfer occurring at each axle of the vehicle as a function of lateral acceleration.

The output of interest from the static roll model is the roll angle, and lateral acceleration at lift off. It can be seen in figure 3.4, as the centre of gravity of the trailer is increased the lateral acceleration required for axle lift of is reduced.




FIGURE(4.1.2): Graphs to show how log length effects the SRT for various trailer designs

### 4.1.2 RESULTS

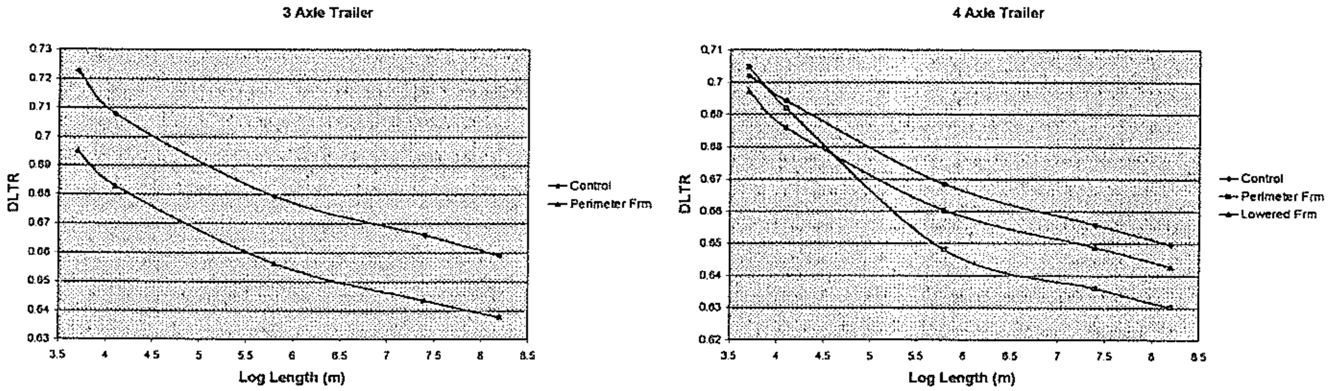
Can only lower the centre of gravity by a small amount due to clearance at the gooseneck.

The values show that the 4 axle control trailer generally performs better. In the case of the 3 axle trailers, for a log size of 3.7m an improvement of 3.4% is seen. This percentage increase becomes 16.3% when 8.2m logs are loaded on. The 4 axle perimeter trailer design shows an increase of 15% for 8.2 m logs, however when 3.7m and 4.1m logs are on the trailer, the SRT is actually worse than the control trailer, showing a decrease of 8%. Lowering of the existing 4 axle trailer frame yields an improvement of 2% for 3.7m logs and 5% for 8.2m logs.

## 4.2 STEADY HANDLING MODEL

### 4.2.1 BACKGROUND

The Steady Turning Model (Handling) examines the steady state (constant Lateral acceleration) yaw and roll response of multiple unit vehicles over the full range of lateral acceleration from 0 up to the point where one wheel of the vehicle lifts off the ground.
The output from this model of interest is the side to side load transfer which is used to calculate the Dynamic Load Transfer Ratio (DLTR). This is an indication of nearness to rollover in a highway speed evasive steering manoeuvre. The truck and trailer combination, will be simulated at a forward speed of 90km/hr, and the DLTR calculated at a 0.15g lateral acceleration.




FIGURE(4.2.1):Graphs to show how log lengths effects the DLTR for various trailer designs.

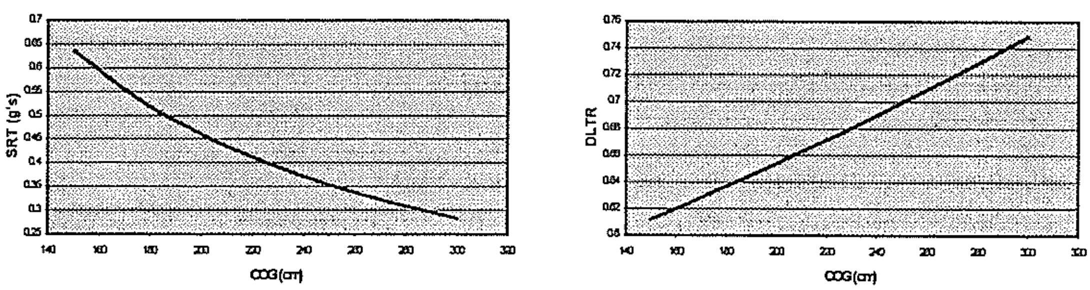
### 4.2.2 RESULTS

As in the static roll model, the 4 axle control trailer model is more stable. Comparing the 3 axle perimeter frame design with the control trailer, the DLTR for 3.7m logs has reduced giving a 2% improvement. For 8.2m logs a 3.3% increase is seen. The 4 axle perimeter frame trailer due to the loading difference of the front and rear axles has made the DLTR compared with the control trailer is worse by 2.6% for 3.7m logs. When larger logs are being used and the load centre can be shifted forwards there is an improvement of 8%. Lowering the existing 4 axle trailer frame gives an improvement of 0.1% for 3.7m logs and 1% for 8.2m logs.

## 4.3 TRENDS

For both models, there are various constants and parameters which must be entered into the program sets. In any of the designing that has been done, the aim is to improve stability. To do this it is important to realise the relevance of these parameters and how they affect stability. To see how stability varies when different variables are changed, both the models have been run at different values for the 3 axle control trailer carrying 3.7m logs.

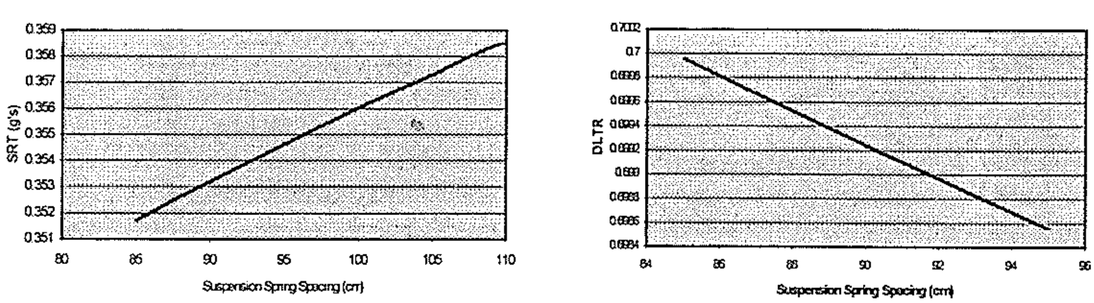
### 4.3.1 CENTRE OF GRAVITY




FIGURE(4.3.1): Graphs to show the effect tat the centre of gravity has on the SRT and DLTR.

A 20% decrease in the centre of gravity results in a 30% improvement in SRT and a 6.5% improvement in the DLTR.

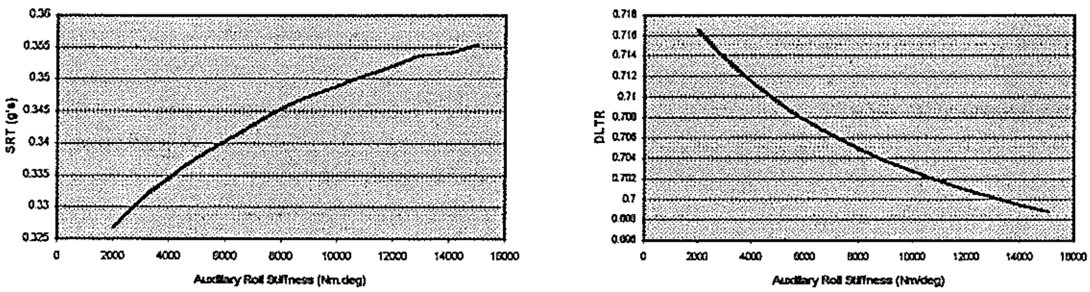
### 4.3.2 SUSPENSION SPRING SPACING




FIGURE(4.3.2): Graphs to show the effect that suspension spring spacing has on the SRT and DLRT.

A 20% increase in the suspension spring spacing results in a 1.5% increase in the SRT and a 0.35% reduction in the DLTR.

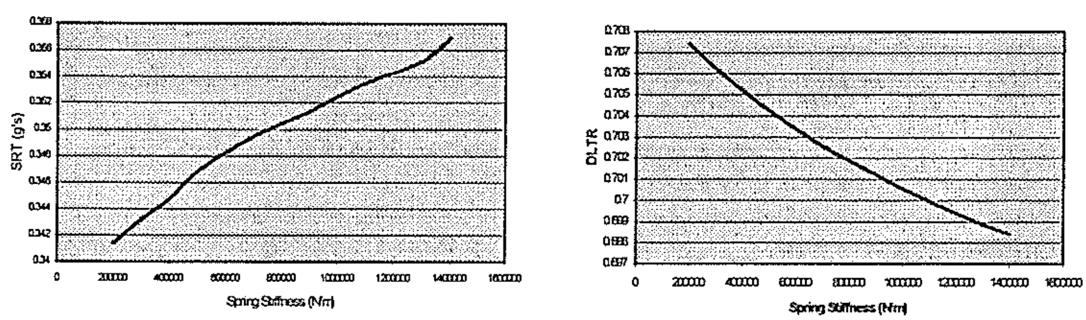
### 4.3.3 AUXILIARY ROLL STIFFNESS




FIGURE(4.3.3): Graphs to show how the auxiliary roll stiffness effects the SRT and DLTR.

A 20% increase in the Auxiliary roll stiffness gives 1% change in the SRT and a 0.24% change in the DLTR.

### 4.3.4 SUSPENSION SPRING STIFFNESS




FIGURE(4.3.4):Graph to show how the spring stiffness effects the SRT and DLTR.

\ 20% increase in the suspension spring stiffness results in a changes of 0.5% and 0.2% respectively in the SRT and the DLTR.

## l.4 SPRING LEAF VS AIR SUSPENSION

.ogging trailers at present, operate under both air and spring leaf suspension systems, however spring leaf ire more popular. Two totally different systems give different driving handling and feel. The main lifferences between the two other than looks are:

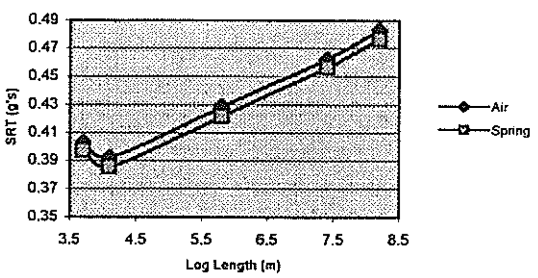
- Geometric differences, the main dimensions here being the ride height and air bag spacing.
- Stiffness: The spring leaf is a lot stiffer than the airbag and so the stiffness coefficient is a lot higher.
- Damping: The air suspension relies a lot more heavily on the damping rather than stiffness, and so has much larger damping.

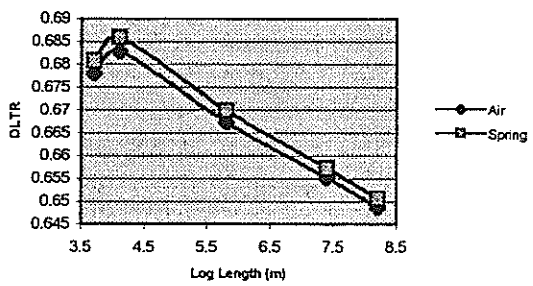
`wo systems have been applied to the 4 axle control trailer. It is assumed that geometrically the two ystems are the same in this case, as this is quite possible. However the stiffness and damping values are lifferent. Air suspension used is, Airlight Suspension, ALO/-D30k and the spring leaf used is Hutch 360-!0 high arch, single leaf.

Stiffness and Damping values are:-

| | Air Suspension | Spring Leaf |
|---|---|---|
| **Spring Stiffness (N/m)** | 245,000 | 1,437,400 |
| **Auxiliary Roll Stiffness (NM.deg)** | 15,465 | 3846 |

4.4.1 RESULTS




FIGURE(4.4.1): Graphs to show comparisons between air and spring leaf suspension systems.

As can be seen from the graphs, air suspension stacks up slightly better than the spring leaf system. There is an improvement of 1.5% in the SRT and an improvement of 0.5% in the DLTR.

## 4.5 CONCLUSIONS

Looking at the various trends amongst the input variables it can be seen how the SRT and DLTR change with different parameters. What is even more important is to know how much of an effect a change in these parameters has on the stability figures.

In both the SRT and DLTR cases, a 20% change in the centre of gravity of the trailer has the greatest effect, this being an increase of 30% in the SRT and an increase of 6.5% in the DLTR. For all the other cases, a 20% change in the parameters causes less than 1.5% change in the stability figures. These calculated figures assume that the functions are linear. This is not in fact the case however over the feasible range which we are dealing with, linearity is not a bad assumption.

Comparing the designs, it can be seen that there is a general trend for the 4 axle trailer to be more stable. The 3 axle trailer has shown an average improvement of around 10% in the SRT and an improvement of 3% in the DLTR. The perimeter frame depending on what size log is used will have significantly different loading on the front and rear axis. When shorter logs are used, so that they fit on the bolsters, the load centre has to be shifted back causing a deterioration in the stability figures. This design has shown improvements in stability for 5.8-8.2 m logs however for smaller lengths, instability is a problem and depending on the applications of the trailer is not really suitable. The lowered design of the current 4 axle trailer is showing improvements although not as significant as that of the 3 axle trailer. Comparing air systems with spring leaf design, stability improves slightly for an air suspension. This variation could also be increased depending on the geometric configuration. The stability analysis data can be seen in Appendix 4.

# 5.0 STRESS ANALYSIS

## 5.1 MSC/Nastran MODELS

All of the trailers have been computer modelled on a finite element based program MSC/Nastran. The program represents the trailers with a series of nodes and elements, of which various loading conditions are applied. In the model a spring leaf suspension system is used, and all measurements are taken as the worst possible scenario to give a conservative approach.

Output required from the models is Stress intensity, and deflections. Section properties of various members in the models have been varied so that stress and deflection values are within allowable limits.
Common practice is to use a 2- 2.5 on yield safety factor. For 350MPa steel, the allowable stress limit becomes, 140MPa. For high tensile steel, the yield strength goes up to 620MPa which would result in a much larger allowable stress limit. Effects of welding causes the strength of high tensile steel to dramatically decrease. For this reason, an allowable stress of 140MPa will be assumed appropriate in this design project.

All of the stress contours for the three designs are shown in appendix 5.

## 5.2 THREE AXLE TRAILER

The perimeter frame shows its highest stress values where the ends of the front bolster meet the outer frame. Stress levels reach 99MPa at this point. This is below the allowable stress of 140MPa and so is satisfactory.

Deflection in the frame reaches 10mm at the gooseneck. This will still allow sufficient clearance with the front dolly axles, and so is alright.

## 5.3 FOUR AXLE TRAILERS

### 5.3.1 PERIMETER FRAME

This trailer is very similar in design to the 3 axle trailer and so the stress field are very similar. Maximum stress is shown at the same point at a value of 120MPa.

Deflection in the frame reaches 10mm at the gooseneck position.

### 5.3.2 EXISTING TRAILER LOWERED

This design is the same as the existing one, and has been lowered through section depths, and small changes in geometry. The maximum stress is 117MPa, however this can by additional strapping.

The slightly larger stress in this case causes an increased deflection in the trailer. Again at the gooseneck area the deflection is 14mm.

# 6.0 WEIGHTS AND LOAD INFORMATION

## 6.1 3 AXLE TRAILER

| | CONTROL | TTL Design | % CHANGE | |
|---|---|---|---|---|
| **TARE WEIGHTS** | 4250 | 4400 | 4% | Bad |
| **GROSS VEHICLE MASS** | 21500 | 21500 | 0% | No Change |
| **LOAD CHARACTERISTICS** | | | | |
| **3.7m LOGS** | | | | |
| Payload (kg) | 17250 | 17100 | -1% | Bad |
| Height of Trailer (mm) | 4230 | 3950 | -7% | Good |
| Centre of Gravity (mm) | 2388 | 2168 | -9% | Good |
| **4.1m LOGS** | | | | |
| Payload (kg) | 17250 | 17100 | -1% | Bad |
| Height of Trailer (mm) | 3950 | 3680 | -7% | Good |
| Centre of Gravity (mm) | 2278 | 2053 | -10% | Good |
| **5.8m LOGS** | | | | |
| Payload (kg) | 17250 | 17100 | -1% | Bad |
| Height of Trailer (mm) | 3330 | 3060 | -8% | Good |
| Centre of Gravity (mm) | 2030 | 1809 | -11% | Good |
| **7.4m LOGS** | | | | |
| Payload (kg) | 17250 | 17100 | -1% | Bad |
| Height of Trailer (mm) | 3030 | 2770 | -9% | Good |
| Centre of Gravity (mm) | 1909 | 1696 | -11% | Good |
| **8.2m LOGS** | | | | |
| Payload (kg) | 17250 | 17100 | -1% | Bad |
| Height of Trailer (mm) | 2870 | 2610 | -9% | Good |
| Centre of Gravity (mm) | 1845 | 1634 | -11% | Good |

The perimeter frame gives rise to an estimate of 150kg in tare weight. This means that the maximum payload of the trailer is reduced by 150kg. At maximum payload for all length logs the perimeter frame gives an average improvement of 8% in the height of the trailer, which in turn prudes a 10% reduction in the height of the centre of gravity.

## 6.2 4 AXLE TRAILERS

### 6.2.1 PERIMETER FRAME DESIGN

| | CONTROL | TTL Design I | % CHANGE | |
|---|---|---|---|---|
| **TARE WEIGHTS** | 4750 | 4900 | 3% | Bad |
| **GROSS VEHICLE MASS** | 22500 | 22500 | 0% | No Change |
| **LOAD CHARACTERISTICS** | | | | |
| **3.7m LOGS** | | | | |
| Payload (kg) | 17399 | 17600 | 1% | Good |
| Height of Trailer (mm) | 4250 | 4030 | -5% | Good |
| Centre of Gravity (mm) | 2345 | 2158 | -8% | Good |
| **4.1m LOGS** | | | | |
| Payload (kg) | 17750 | 17600 | -1% | Bad |
| Height of Trailer (mm) | 4020 | 3750 | -7% | Good |
| Centre of Gravity (mm) | 2263 | 2048 | -10% | Good |
| **5.8m LOGS** | | | | |
| Payload (kg) | 17750 | 17600 | -1% | Bad |
| Height of Trailer (mm) | 3390 | 3120 | -8% | Good |
| Centre of Gravity (mm) | 2012 | 1801 | -10% | Good |
| **7.4m LOGS** | | | | |
| Payload (kg) | 17750 | 17600 | -1% | Bad |
| Height of Trailer (mm) | 3080 | 2810 | -9% | Good |
| Centre of Gravity (mm) | 1890 | 1681 | -11% | Good |
| **8.2m LOGS** | | | | |
| Payload (kg) | 17750 | 17600 | -1% | Bad |
| Height of Trailer (mm) | 2910 | 2650 | -9% | Good |
| Centre of Gravity (mm) | 1825 | 1618 | -11% | Good |

The maximum payload of the trailer is reduced by 150Kg, as there is an estimated increase in the tare weights. With the 4 axle control trailer, in the case of 3.7m logs, the maximum payload cannot be reached due to the height restriction. The payload on the perimeter frame design for 3.7m is increased by 1% to it's maximum payload. For all of the log lengths, there is an improvement in trailer height and a reduction in the centre of gravity.

## 6.2.2 LOWERED EXISTING TRAILER

| | CONTROL | TTL Design II | % CHANGE | |
|---|---|---|---|---|
| **TARE WEIGHTS** | 4250 | 4250 | 0% | No Change |
| **GROSS VEHICLE MASS** | 21500 | 21500 | 0% | No Change |
| **LOAD CHARACTERISTICS** | | | | |
| **3.7m LOGS** | | | | |
| Payload (kg) | 17399 | 17750 | 2% | Good |
| Height of Trailer (mm) | 4250 | 4210 | -1% | Good |
| Centre of Gravity (mm) | 2345 | 2296 | -2% | Good |
| **4.1m LOGS** | | | | |
| Payload (kg) | 17750 | 17750 | 0% | No Change |
| Height of Trailer (mm) | 4020 | 3920 | -2% | Good |
| Centre of Gravity (mm) | 2263 | 2184 | -3% | Good |
| **5.8m LOGS** | | | | |
| Payload (kg) | 17750 | 17750 | 0% | No Change |
| Height of Trailer (mm) | 3390 | 3290 | -3% | Good |
| Centre of Gravity (mm) | 2012 | 1933 | -4% | Good |
| **7.4m LOGS** | | | | |
| Payload (kg) | 17750 | 17750 | 0% | No Change |
| Height of Trailer (mm) | 3080 | 2980 | -3% | Good |
| Centre of Gravity (mm) | 1890 | 1811 | -4% | Good |
| **8.2m LOGS** | | | | |
| Payload (kg) | 17750 | 17750 | 0% | No Change |
| Height of Trailer (mm) | 2910 | 2810 | -3% | Good |
| Centre of Gravity (mm) | 1825 | 1747 | -4% | Good |

Lowering of the existing control trailer 4 axle frame, gives small overall improvement. For 3.7m logs the maximum payload can be reached instead of being restricted due to legal height limits. The trailer heights and centre of gravity have been improved by an average of about 3%.

# 7.0 CONCLUSIONS

- There are many small changes, such as changing tyres, and suspension set ups that can be made to the existing 3 and 4 axle trailers to lower the trailer height, however none of these will have a significant effect on their own.

- A 3 axle perimeter frame has been shown as the best solution to increasing stability. Compared with the current 3 axle trailers, the maximum payload will be reduced due to the increase in tare weight. The centre of gravity and total trailer height for all lengths of logs offer significant improvements in stability.

- The 4 axle perimeter frame gives significant improvements similar to that of the 3 axle trailer for longer logs. When short logs are being carried, stability is worse than the control trailer and should not be used in this case.

- Lowering of the existing trailer designs can be achieved through changing sections and accurate stress analysis. This will give an improvement in stability about half that of the perimeter frame.
- Using low profile tyres can lower all of the new designs even more. Tyre change is a good option because the gooseneck clearance is not an issue as the smaller the diameter the further away from the gooseneck the tyres are.

- Air suspension shows slight improvement in the stability. It is desirable in whatever suspension system used, that the spring spacing is at a maximum.

# 8.0 DISCUSSIONS

- The trailer length is limited due to the rear overhang on the truck when piggybacking and also the 20m road legal length for a truck and trailer. If this limit was to be increased then double bunking logging trailers can be used. Depending on how much the trailer wheelbase can be extended, a frame could be designed so that for the shorter logs, they fit down between the front dolly and rear axles, utilising the dead space. This will significantly improve stability.

- Modifying log loaders will change the amount of space required for loading and unloading the logs. This will cause more leeway in the parameter, giving an even better improved design.

# 9.0 REFERENCES

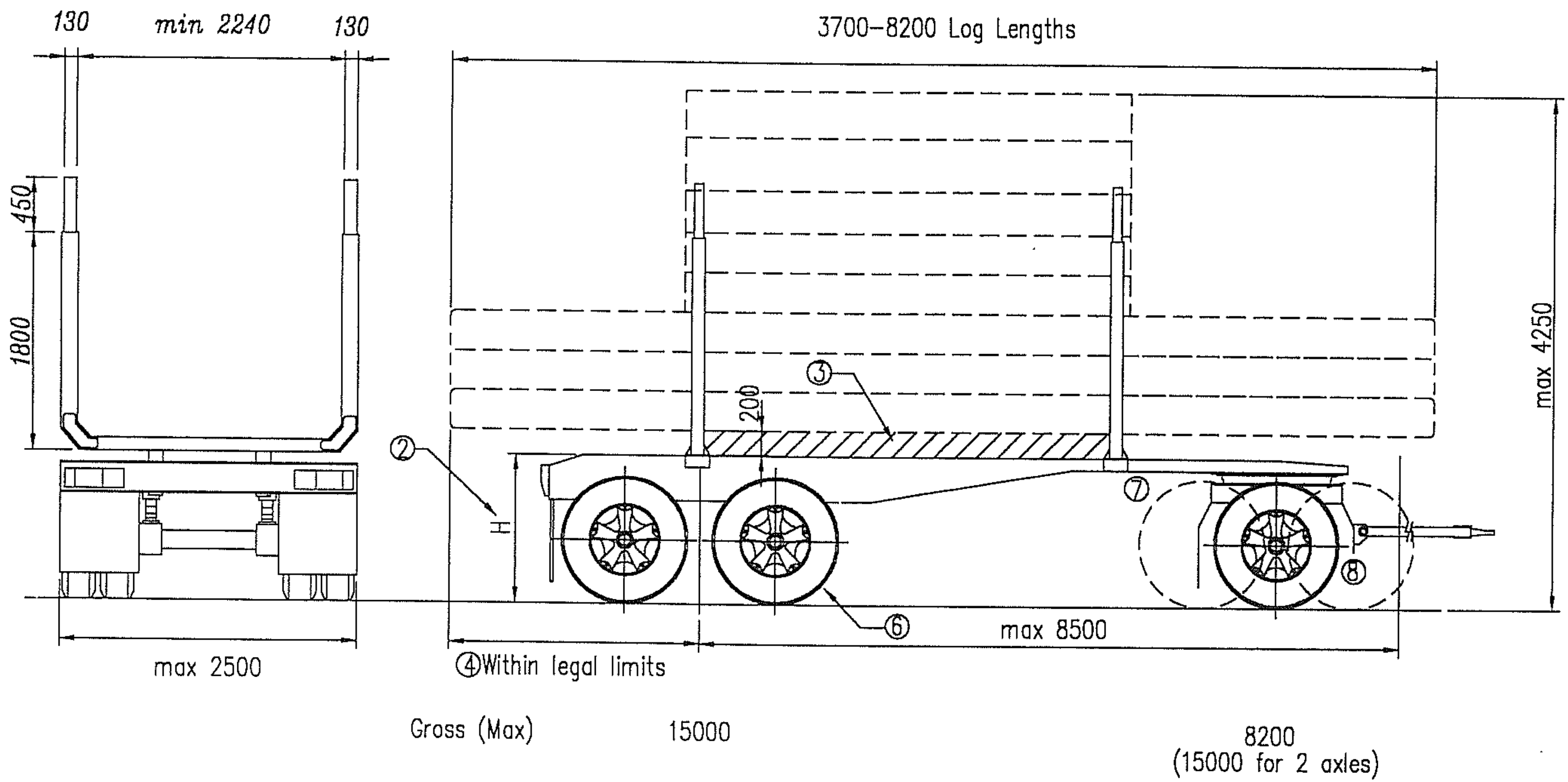

1. UMTRI (1988). Simplified Models of Truck Braking and Handling. The University of Michigan Transportation Research Institute.

2. Bass P, Latto D (1997). Logging Truck Stability Analysis, Transport Engineering Research New Zealand Limited. (TERNZ)

3. LTSA. Transport Technology Report.

## APPENDIX 1

# DESIGN PARAMETERS




| otes | |
|---|---|
| | Items in italics are common industry measurements |
| | Want to minimise this value to lower the centre of gravity |
| | Fixed space for log loading and unloading |
| | Distance must not exceed the maximum rear overhang limit of truck when piggybacking |

| Trailer Modifications to improve stability | |
|---|---|
| 5 | Alter suspension, either by changing type or modifying geometry |
| 6 | Use low profile tyres |
| 7 | Change the geometry of the trailer |
| 8 | Use different steering mechanism |

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Parameters For Logging Trailer
LIRO Forestry Solutions

| | | | |
|---|---|---|---|
| 560417 | | | Sheet: 01 |
| Drawn: H.B | Issue: A | Chkd: | |
| Ref: 10000 | Date: 19/11/98 | Scale: 1:50 | Date: |

## APPENDIX 2

# Load Calculations Spreadsheet

# CENTER OF GRAVITY CALCULATIONS

DATE: 8/02/99 TIME : 15:54

CLIENT: LIRO JOB : 10000 BY: HB

FILE: C:\10000\Spreadsheets\[3ax_ctrl_COG_calcs.xls]Sheet1

TRAILER DESCRIPTION: 3 axle control trailer logging shorts

Wheelbase 4.4 m

| OBJECT / APPLIANCE | | MASS | CO-ORDINATES | | | | |
|---|---|---|---|---|---|---|---|
| X taken from front axis | qty | Kg | X | Y | Xm^2 | Ym^2 | Mass |
| **Dolly** | | | | | | | |
| Axles | 1 | 351 | 0 | 0.438 | 0.00 | 153.74 | 351 |
| Wheels | 4 | 101 | 0 | 0.438 | 0.00 | 176.95 | 404 |
| Suspension | 1 | 154 | 0 | 0.6 | 0.00 | 92.40 | 154 |
| Dolly | 1 | 286 | 0 | 0.9 | 0.00 | 257.40 | 286 |
| Brakes | 1 | 30 | 0 | 0.438 | 0.00 | 13.14 | 30 |
| **Semi Trailer** | | | | Totals | 0.00E+00 | 6.94E+02 | 1.23E+03 |
| Axles | 2 | 351 | 4.4 | 0.438 | 3088.80 | 307.48 | 702 |
| Wheels | 8 | 101 | 4.4 | 0.438 | 3555.20 | 353.90 | 808 |
| Suspension | 2 | 154 | 4.4 | 0.6 | 1355.20 | 184.80 | 308 |
| semi trailer | 1 | 1147 | 3.727 | 1.1 | 4274.87 | 1261.70 | 1147 |
| Brakes | 2 | 30 | 4.4 | 0.438 | 264.00 | 26.28 | 60 |
| | | | | Totals | 12538.07 | 2134.16 | 3025.00 |

**Dolly**

| | X | Y | |
|---|---|---|---|
| Centre of Gravity | 0 | 0.566228571 | m |
| Mass | 1225 | kg | |

**Semi Trailer**

| | X | Y | |
|---|---|---|---|
| Centre of Gravity | 4.14 | 0.705507438 | m |
| Mass | 3025 | kg | |

**Log Details**

| | | |
|---|---|---|
| Density | 1000 | kg/m^3 |
| Load Width | 2.2 | m |

**Tare Weights**

| | | |
|---|---|---|
| Front | 1400 | kg |
| Rear | 2850 | kg |
| Allowable Payload | 17250 | kg |

**Parameters**

| | | |
|---|---|---|
| Max GVM Trailer | 21500 | m |
| Max Height | 4.25 | m |
| Ground to load | 1.4 | m |
| Load Height | 2.85 | m |

**Log Size**

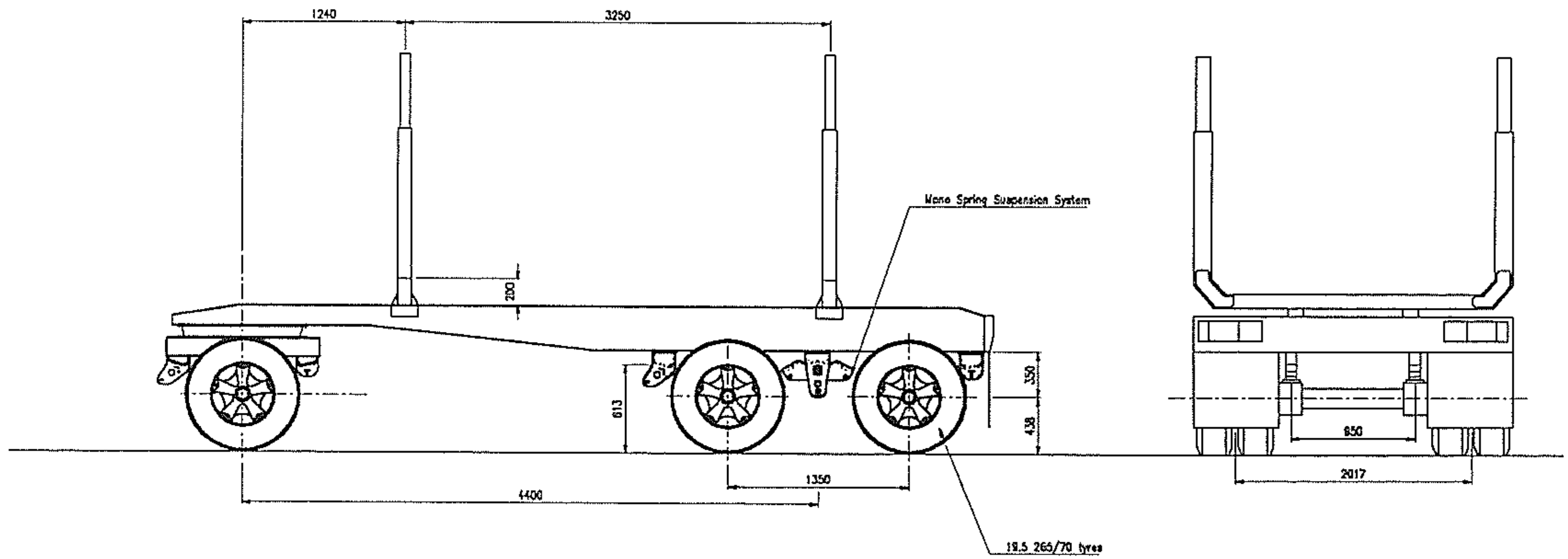
| | | | | | | |
|---|---|---|---|---|---|---|
| Load Centre frm frnt axis | 2.8442 | 2.8442 | 2.8442 | 2.8442 | 2.8442 | |
| Log Length | 3.7 | 4.1 | 5.8 | 7.4 | 8.2 | m |
| Stacking Ratio | 0.75 | 0.75 | 0.7 | 0.65 | 0.65 | |
| Weight at Maximum Height | 17399 | 19280 | 25456 | 30159 | 33419 | kg |
| At maximum payload | 2.83 | 2.55 | 1.93 | 1.63 | 1.47 | m |
| Limiting Factor | Weight | Weight | Weight | Weight | Weight | |
| COG | 2.81 | 2.67 | 2.37 | 2.22 | 2.14 | m |

## RESULTS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Actual Payload** | | 17250.00 | 17250.00 | 17250.00 | 17250.00 | 17250.00 | kg |
| **Actual Height** | | 4.23 | 3.95 | 3.33 | 3.03 | 2.87 | m |
| **COG of Semitrailer** | | 2.50 | 2.38 | 2.12 | 1.99 | 1.92 | m |
| **Weight of Semitrailer** | | 20275.00 | 20275.00 | 20275.00 | 20275.00 | 20275.00 | kg |
| **COG of Trailer** | X | 2.865140419 | 2.865140419 | 2.865140419 | 2.865140419 | 2.865140419 | m |
| | Y | 2.388287587 | 2.277701572 | 2.029529938 | 1.908727078 | 1.844927454 | m |
| Axle Loads | Front | 73573.84287 | 73573.84287 | 73573.84287 | 73573.84287 | 73573.84287 | N |
| | Rear | 68670.57857 | 68670.57857 | 68670.57857 | 68670.57857 | 68670.57857 | N |
| Gross Vehicle Mass | | | | | | | |
| | Front | 7500 | 7500 | 7500 | 7500 | 7500 | kg |
| | Rear | 14000 | 14000 | 14000 | 14000 | 14000 | kg |
| | Total | 21500 | 21500 | 21500 | 21500 | 21500 | kg |

**APPENDIX 3**

# 3 & 4 Axle Control Trailers




| | | | TOTAL |
|---|---|---|---|
| TARE | 1400 | 2850 | 4250 |
| GROSS | 7500 | 14000 | 21500 |

| ISSUE | DATE | CHANGES MADE | BY |
|---|---|---|---|
| C | | | |
| B | | | |
| A | | | HB |

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CNR ALLENS ROAD & ZELANIAN DRIVE,
EAST TAMAKI, AUCKLAND.
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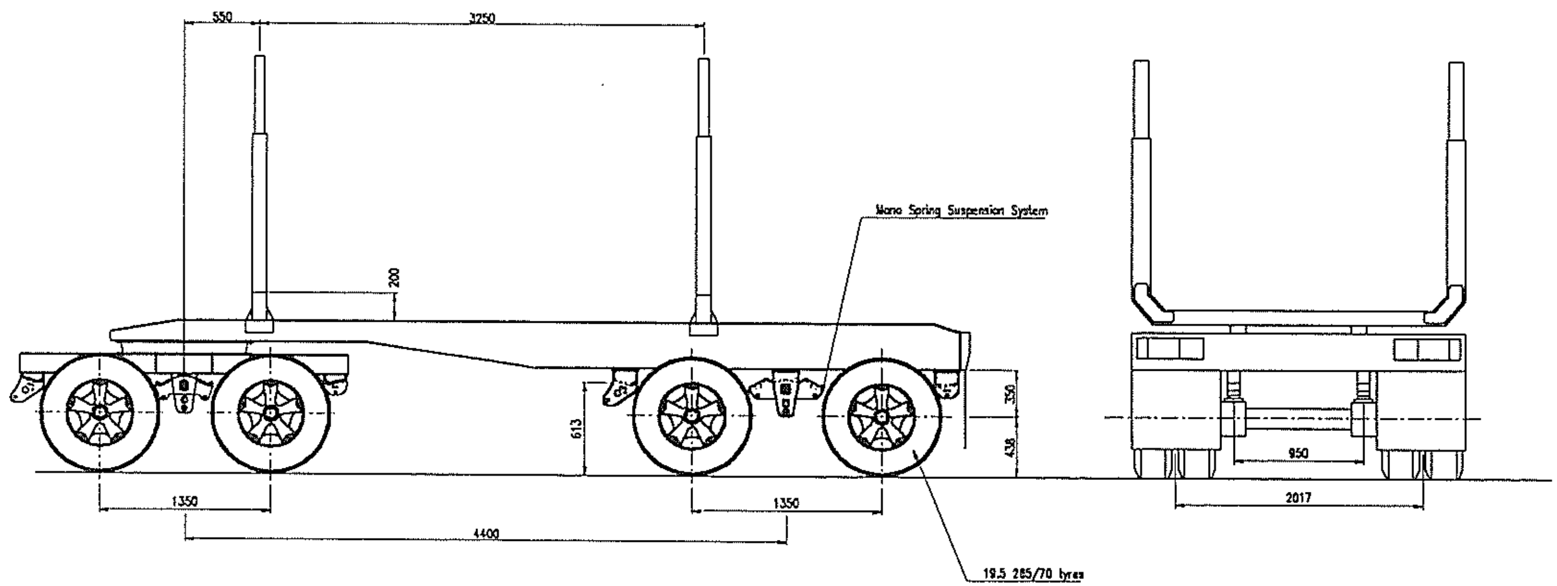
# 3 AXLE CONTROL TRAILER

CLIENT: LIRO

560416

Sheet: 01

Drawn: 22/1/99 | Issue: A | Chkd:
Date: 22/1/99 | Scale: 1:40 | Date:
Ref: 10000




| | | | TOTAL |
|---|---|---|---|
| TARE | 2550 | 2250 | 4750 |
| GROSS | 11250 | 11250 | 22500 |

| ISSUE | DATE | CHANGES MADE | BY |
|---|---|---|---|
| C | | | |
| B | | | |
| A | | | HB |

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PHONE (09) 274-8911 FAX (09) 274-5006

# 4 AXLE CONTROL TRAILER

CLIENT: LIRO

| | | | |
|---|---|---|---|
| 560416 | | | Sheet: 02 |
| Drawn: 22/1/99 | Issue: A | Chkd: | |
| Ref: 10000 | Date: 22/1/99 | Scale: 1:40 | Date: |

## APPENDIX 4

# Stability Data

## STABILITY ANALYSIS INFORMATION

### 3 Axle Control Trailer

| | Log Length | COG | Roll Angle | SRT | Axle load | Load Transfer | DLTR |
|---|---|---|---|---|---|---|---|
| Axle 1 | 3.7 | 239 | 0.082 | 0.34112 | 73574 | 15480.33 | 0.710405 |
| | 4.1 | 228 | 0.08 | 0.36411 | 73574 | 14454.53571 | 0.696463 |
| | 5.8 | 203 | 0.076 | 0.42161 | 73574 | 12504.11143 | 0.669953 |
| | 7.4 | 191 | 0.073 | 0.45651 | 73574 | 11576.82 | 0.657349 |
| | 8.2 | 184 | 0.072 | 0.47644 | 73574 | 11089.95 | 0.650732 |
| | | | | | | | |
| Axle 2 | 3.7 | 239 | 0.077 | 0.33874 | 68670 | 15292.575 | 0.722697 |
| | 4.1 | 228 | 0.075 | 0.36099 | 68670 | 14269.23 | 0.707794 |
| | 5.8 | 203 | 0.071 | 0.41821 | 68670 | 12324.12 | 0.679469 |
| | 7.4 | 191 | 0.069 | 0.45263 | 68670 | 11399.79857 | 0.666008 |
| | 8.2 | 184 | 0.067 | 0.47205 | 68670 | 10914.65571 | 0.658944 |
| | | | | | | | |
| Axle 3 | 3.7 | 239 | 0.077 | 0.33874 | 68670 | 15294.61 | 0.722726 |
| | 4.1 | 228 | 0.075 | 0.36099 | 68670 | 14271.08143 | 0.707821 |
| | 5.8 | 203 | 0.071 | 0.41821 | 68670 | 12325.61571 | 0.679491 |
| | 7.4 | 191 | 0.069 | 0.45263 | 68670 | 11401.12286 | 0.666028 |
| | 8.2 | 184 | 0.067 | 0.47205 | 68670 | 10915.88571 | 0.658961 |

### 3 Axle Perimeter Frame Design

| | Log Length | COG | Roll Angle | SRT | Axle load | Load Transfer | DLTR |
|---|---|---|---|---|---|---|---|
| Axle 1 | 3.7 | 217 | 0.079 | 0.3883 | 73833 | 13547.53714 | 0.683489 |
| | 4.1 | 206 | 0.077 | 0.41379 | 73833 | 12732.03857 | 0.672444 |
| | 5.8 | 182 | 0.071 | 0.48597 | 73833 | 10893.10714 | 0.647537 |
| | 7.4 | 170 | 0.068 | 0.52924 | 73833 | 10017.33 | 0.635676 |
| | 8.2 | 163 | 0.067 | 0.55086 | 73833 | 9622.367143 | 0.630326 |
| | | | | | | | |
| Axle 2 | 3.7 | 217 | 0.073 | 0.3851 | 68540 | 13350.16286 | 0.694779 |
| | 4.1 | 206 | 0.071 | 0.40993 | 68540 | 12537.12857 | 0.682917 |
| | 5.8 | 182 | 0.067 | 0.48134 | 68540 | 10704.76714 | 0.656183 |
| | 7.4 | 170 | 0.064 | 0.52393 | 68540 | 9832.847143 | 0.643461 |
| | 8.2 | 163 | 0.062 | 0.54482 | 68540 | 9439.847143 | 0.637728 |
| | | | | | | | |
| Axle 3 | 3.7 | 217 | 0.073 | 0.3851 | 68540 | 13351.87714 | 0.694804 |
| | 4.1 | 206 | 0.071 | 0.40993 | 68540 | 12538.69286 | 0.68294 |
| | 5.8 | 182 | 0.067 | 0.48134 | 68540 | 10705.98 | 0.6562 |
| | 7.4 | 170 | 0.064 | 0.52393 | 68540 | 9833.888571 | 0.643477 |
| | 8.2 | 163 | 0.062 | 0.54482 | 68540 | 9440.807143 | 0.637742 |

## 4 Axle Control Trailer

| | Log Length | COG | Roll Angle | SRT | Axle load | Load Transfer | DLTR |
|---|---|---|---|---|---|---|---|
| Axle 1 | 3.7 | 235 | 0.06 | 0.37108 | 54333 | 10977.33 | 0.702038 |
| | 4.1 | 226 | 0.06 | 0.38597 | 55181 | 10719.79286 | 0.694266 |
| | 5.8 | 201 | 0.057 | 0.44502 | 55181 | 9287.571429 | 0.668311 |
| | 7.4 | 189 | 0.055 | 0.48068 | 55181 | 8599.118571 | 0.655835 |
| | 8.2 | 183 | 0.054 | 0.50026 | 55181 | 8261.494286 | 0.649716 |
| | | | | | | | |
| Axle 2 | 3.7 | 235 | 0.06 | 0.37108 | 54333 | 10975.88143 | 0.702011 |
| | 4.1 | 226 | 0.06 | 0.38597 | 55181 | 10718.4 | 0.694241 |
| | 5.8 | 201 | 0.057 | 0.44502 | 55181 | 9286.444286 | 0.668291 |
| | 7.4 | 189 | 0.055 | 0.48068 | 55181 | 8598.12 | 0.655817 |
| | 8.2 | 183 | 0.054 | 0.50026 | 55181 | 8260.56 | 0.649699 |
| | | | | | | | |
| Axle 3 | 3.7 | 235 | 0.06 | 0.37108 | 54309 | 10974.95143 | 0.702083 |
| | 4.1 | 226 | 0.06 | 0.38597 | 55181 | 10718.35714 | 0.69424 |
| | 5.8 | 201 | 0.057 | 0.44502 | 55181 | 9286.41 | 0.66829 |
| | 7.4 | 189 | 0.055 | 0.48068 | 55181 | 8598.09 | 0.655816 |
| | 8.2 | 183 | 0.054 | 0.50026 | 55181 | 8260.534286 | 0.649699 |
| | | | | | | | |
| Axle 4 | 3.7 | 235 | 0.06 | 0.37108 | 54309 | 10976.47286 | 0.702111 |
| | 4.1 | 226 | 0.06 | 0.38597 | 55181 | 10719.81857 | 0.694266 |
| | 5.8 | 201 | 0.057 | 0.44502 | 55181 | 9287.592857 | 0.668311 |
| | 7.4 | 189 | 0.055 | 0.48068 | 55181 | 8599.135714 | 0.655835 |
| | 8.2 | 183 | 0.054 | 0.50026 | 55181 | 8261.511429 | 0.649717 |

## 4 Axle Perimeter Frame Design

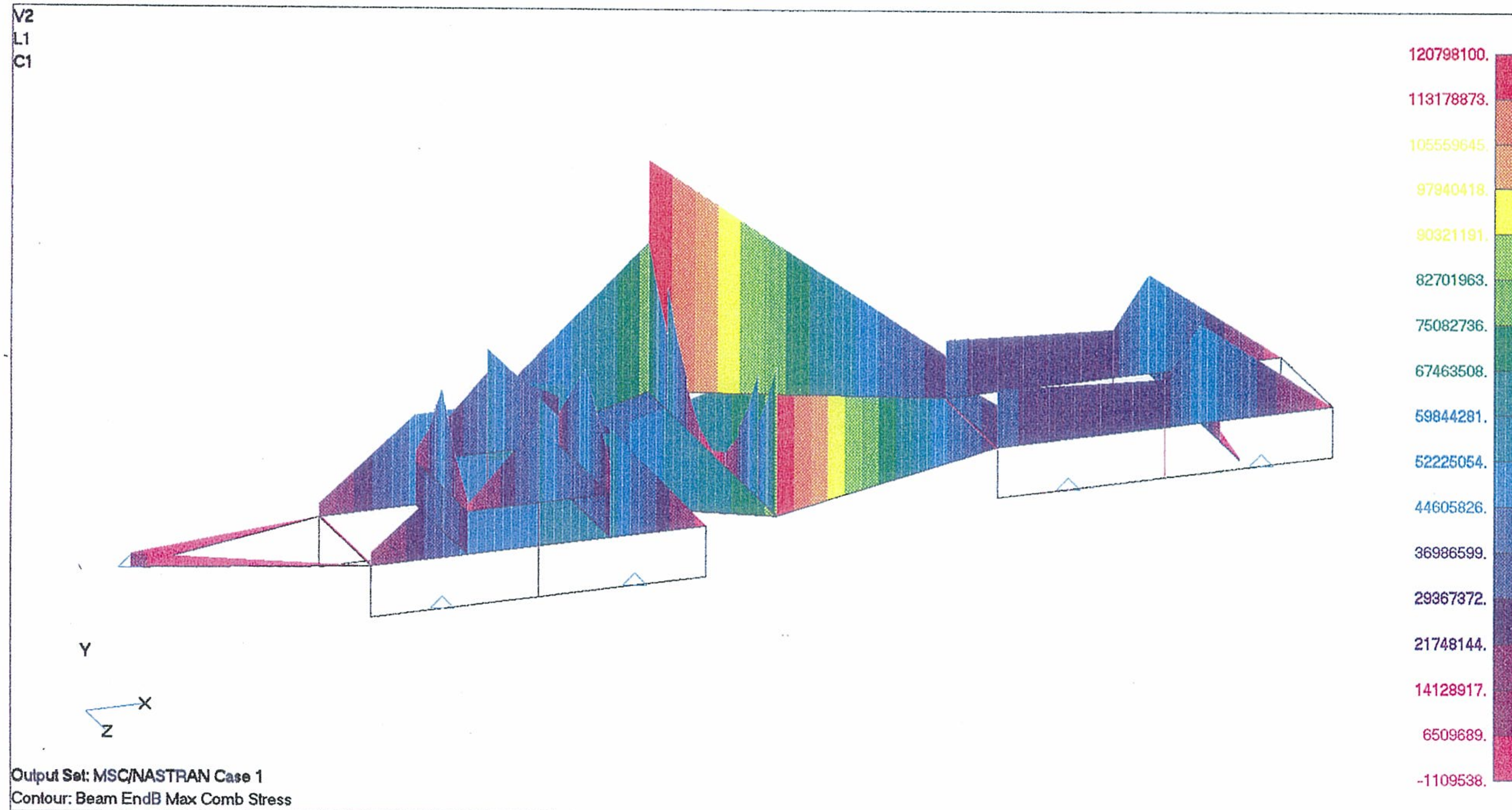
| | Log Length | COG | Roll Angle | SRT | Axle load | Load Transfer | |
|---|---|---|---|---|---|---|---|
| Axle 1 | 3.7 | 216 | 0.045 | 0.31445 | 39974 | 8180.944286 | 0.704657 |
| | 4.1 | 205 | 0.044 | 0.33579 | 39974 | 7664.014286 | 0.691725 |
| | 5.8 | 180 | 0.054 | 0.50581 | 55179 | 8165.751429 | 0.647987 |
| | 7.4 | 168 | 0.051 | 0.551 | 55179 | 7505.695714 | 0.636024 |
| | 8.2 | 162 | 0.05 | 0.57558 | 55179 | 7181.867143 | 0.630156 |
| | | | | | | | |
| Axle 2 | 3.7 | 216 | 0.045 | 0.31445 | 39974 | 8179.92 | 0.704631 |
| | 4.1 | 205 | 0.044 | 0.33579 | 39974 | 7663.084286 | 0.691702 |
| | 5.8 | 180 | 0.054 | 0.50581 | 55179 | 8164.838571 | 0.64797 |
| | 7.4 | 168 | 0.051 | 0.551 | 55179 | 7504.911429 | 0.63601 |
| | 8.2 | 162 | 0.05 | 0.57558 | 55179 | 7181.147143 | 0.630143 |
| | | | | | | | |
| Axle 3 | 3.7 | 216 | 0.75 | 0.39338 | 70389 | 9125.961429 | 0.62965 |
| | 4.1 | 205 | 0.73 | 0.42017 | 70389 | 8598.848571 | 0.622162 |
| | 5.8 | 180 | 0.054 | 0.50581 | 55183 | 8164.95 | 0.647961 |
| | 7.4 | 168 | 0.051 | 0.551 | 55183 | 7505.022857 | 0.636002 |
| | 8.2 | 162 | 0.05 | 0.57558 | 55183 | 7181.262857 | 0.630135 |
| | | | | | | | |
| Axle 4 | 3.7 | 216 | 0.75 | 0.39338 | 70389 | 9127.187143 | 0.629668 |
| | 4.1 | 205 | 0.73 | 0.42017 | 70389 | 8599.971429 | 0.622178 |
| | 5.8 | 180 | 0.054 | 0.50581 | 55183 | 8165.91 | 0.647979 |
| | 7.4 | 168 | 0.051 | 0.551 | 55183 | 7505.85 | 0.636017 |
| | 8.2 | 162 | 0.05 | 0.57558 | 55183 | 7182.017143 | 0.630149 |

| 4 Axle Lowered Existing Design | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Log Length | COG | Roll Angle | SRT | Axle load | Load Transfer | DLTR |
| Axle 1 | 3.7 | 230 | 0.061 | 0.3797 | 55181 | 10877.81571 | 0.69713 |
| | 4.1 | 218 | 0.059 | 0.40357 | 55181 | 10251.15429 | 0.685773 |
| | 5.8 | 193 | 0.056 | 0.46715 | 55181 | 8842.958571 | 0.660254 |
| | 7.4 | 181 | 0.054 | 0.50302 | 55181 | 8213.622857 | 0.648849 |
| | 8.2 | 175 | 0.053 | 0.52414 | 55181 | 7880.897143 | 0.642819 |
| | | | | | | | |
| Axle 2 | 3.7 | 230 | 0.061 | 0.3797 | 55181 | 10876.39286 | 0.697104 |
| | 4.1 | 218 | 0.059 | 0.40357 | 55181 | 10249.84714 | 0.68575 |
| | 5.8 | 193 | 0.056 | 0.46715 | 55181 | 8841.912857 | 0.660235 |
| | 7.4 | 181 | 0.054 | 0.50302 | 55181 | 8212.697143 | 0.648832 |
| | 8.2 | 175 | 0.053 | 0.52414 | 55181 | 7880.035714 | 0.642803 |
| | | | | | | | |
| Axle 3 | 3.7 | 230 | 0.061 | 0.3797 | 55181 | 10876.39286 | 0.697104 |
| | 4.1 | 218 | 0.059 | 0.40357 | 55181 | 10249.84714 | 0.68575 |
| | 5.8 | 193 | 0.056 | 0.46715 | 55181 | 8841.912857 | 0.660235 |
| | 7.4 | 181 | 0.054 | 0.50302 | 55181 | 8212.697143 | 0.648832 |
| | 8.2 | 175 | 0.053 | 0.52414 | 55181 | 7880.035714 | 0.642803 |
| | | | | | | | |
| Axle 4 | 3.7 | 230 | 0.061 | 0.3797 | 55181 | 10877.81571 | 0.69713 |
| | 4.1 | 218 | 0.059 | 0.40357 | 55181 | 10251.15429 | 0.685773 |
| | 5.8 | 193 | 0.056 | 0.46715 | 55181 | 8842.958571 | 0.660254 |
| | 7.4 | 181 | 0.054 | 0.50302 | 55181 | 8213.622857 | 0.648849 |
| | 8.2 | 175 | 0.053 | 0.52414 | 55181 | 7880.897143 | 0.642819 |

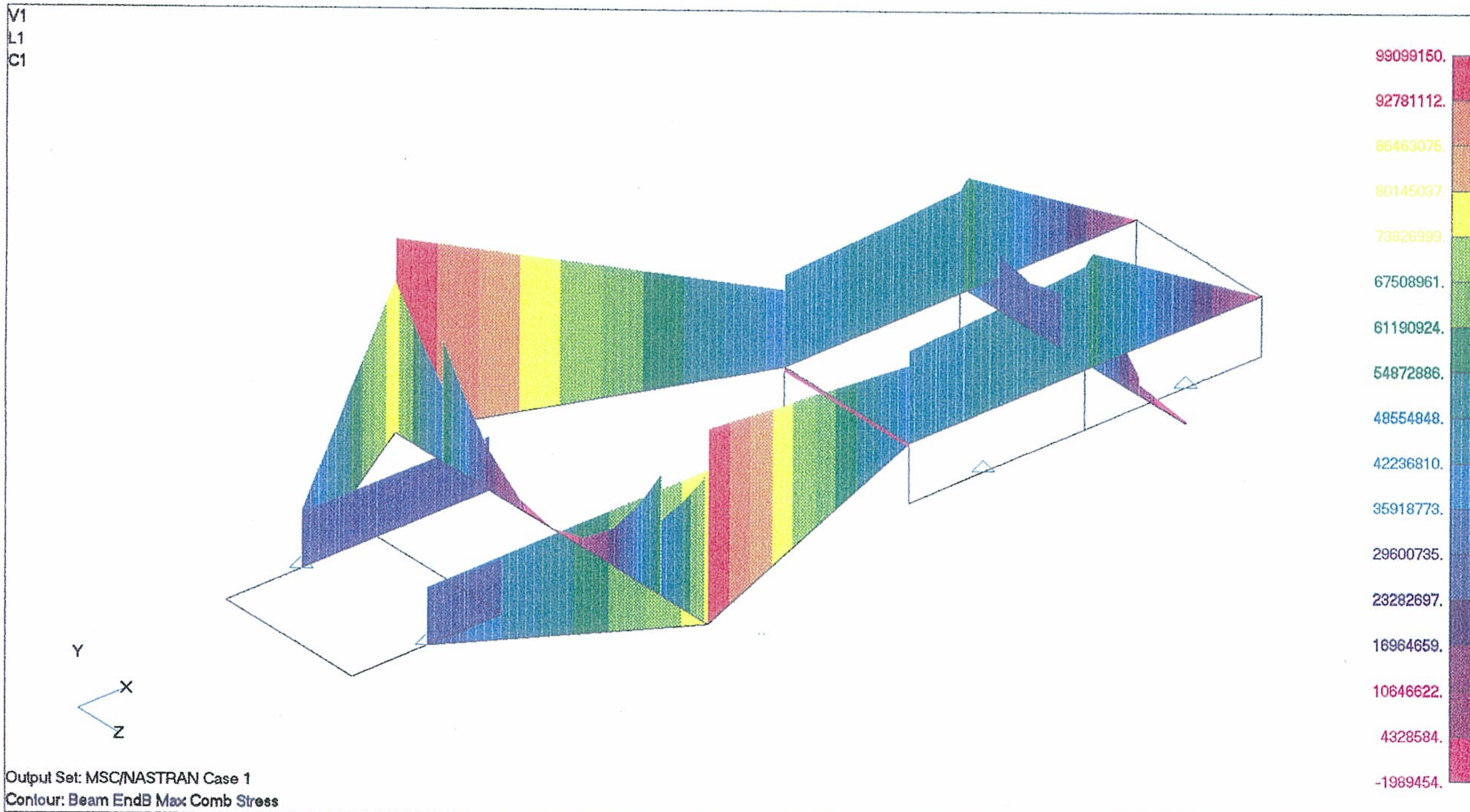
## APPENDIX 5

# Stress Contours for New Designs

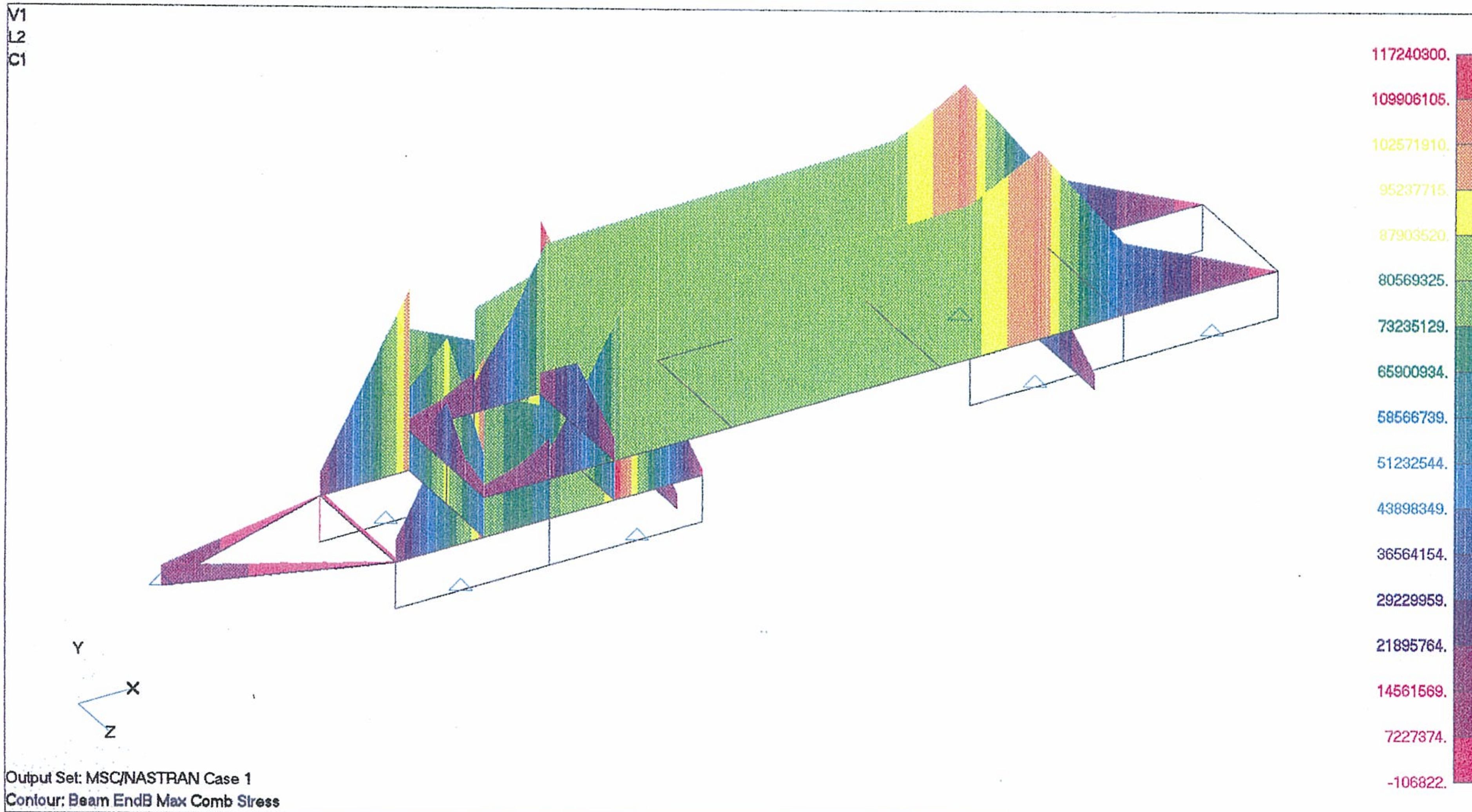
4 Axle Perimeter Frame Design



3 Axle Perimeter Frame Design

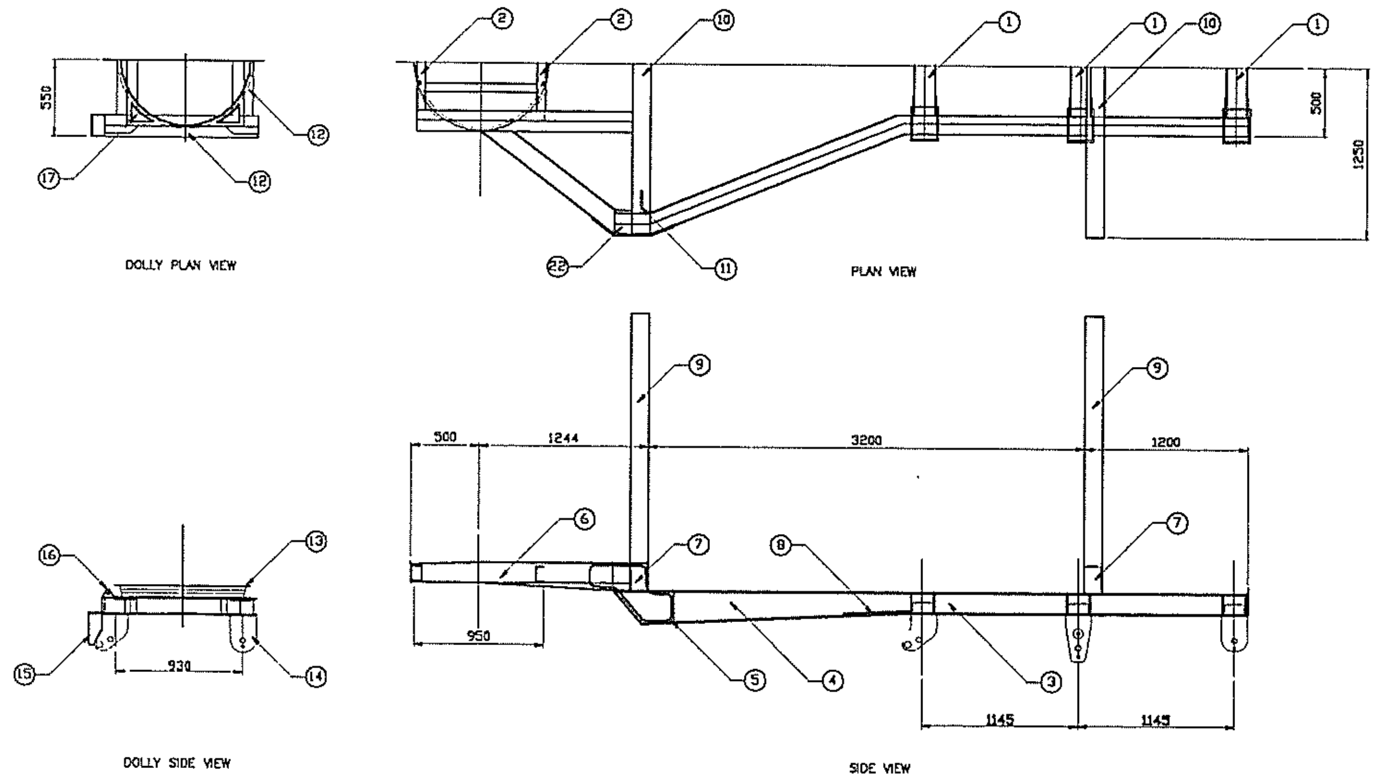


4 Axle Lowered Existing Trailer Design



## APPENDIX 6

# Engineering Drawings and Specifications




| ITEM | QTY | MATERIAL | DESCRIPTION | DRG No. |
|---|---|---|---|---|
| 18 | | | | |
| 17 | 4 | Ex 10mm | GUSSET | |
| 16 | | | DRAWBAR SPRING MOUNT | |
| 15 | 1 | | DRAWBAR HINGE KIT | |
| 14 | 2 | | HANGER | |
| 13 | 1 | | TURNTABLE | |
| 12 | | 100mm deep | DOLLY I-BEAM | |
| 11 | 2 | Ex 10mm | GUSSET | |
| 10 | 2 | 200x130x6 RHS | BOLSTERS | |

| ITEM | QTY | MATERIAL | DESCRIPTION | DRG No. |
|---|---|---|---|---|
| 9 | | 200 x 130 x 6 RHS | STANCHION | |
| 8 | 4 | 60 x 10 Flat | STRAP | |
| 7 | | Ex 10mm | STRAP | |
| 6 | | 150 UC 23.4 | CHASSIS | |
| 5 | 4 | Ex 10 mm | GUSSET | |
| 4 | 2 | I BEAM | TAPERED CHASSIS BEAM | |
| 3 | 2 | 160 deep | CHASSIS I-BEAM | |
| 2 | 2 | 127 x 65 RSC | CROSS MEMBER | |
| 1 | 3 | 150 x 100 x 9 | CROSS MEMBER | |

| ISSUE | DATE | CHANGES MADE | BY |
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CHASSIS DETAILS – 3 AXLE PERIMETER FRAME TRAILER

CLIENT: LIRO

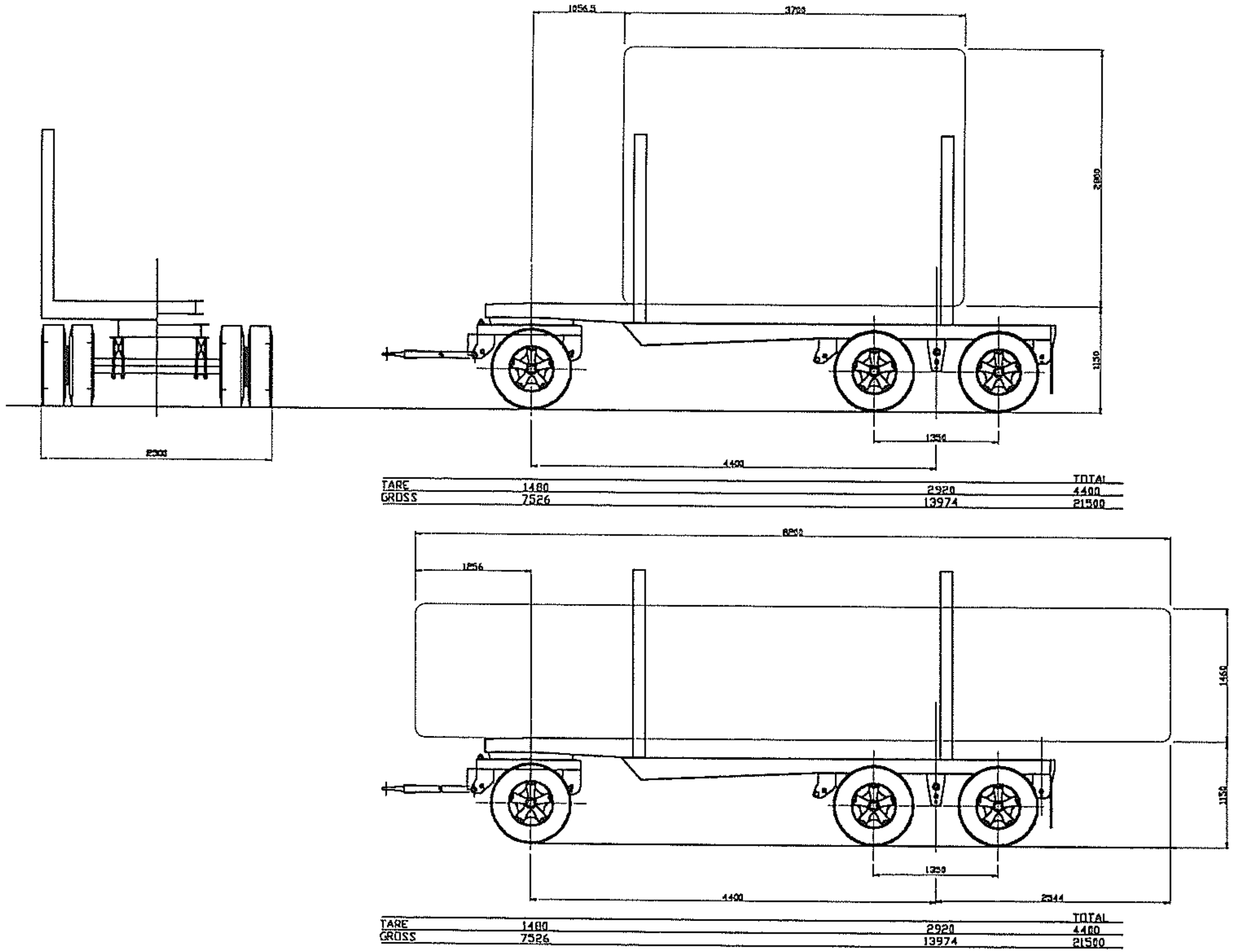
520170

Sheet: 01

Drawn: 4/2/99 | Issue: A | Chkd:

Ref: 10000 | Date: 4/2/99 | Scale: 1:40 | Date:

| LOG LENGTH | TRAILER | |
|---|---|---|
| | PAYLOAD | CoG |
| 3.7 | 17100 | 2.17 |
| 4.1 | 17100 | 2.06 |
| 5.8 | 17100 | 1.82 |
| 7.4 | 17100 | 1.70 |
| 8.2 | 17100 | 1.63 |

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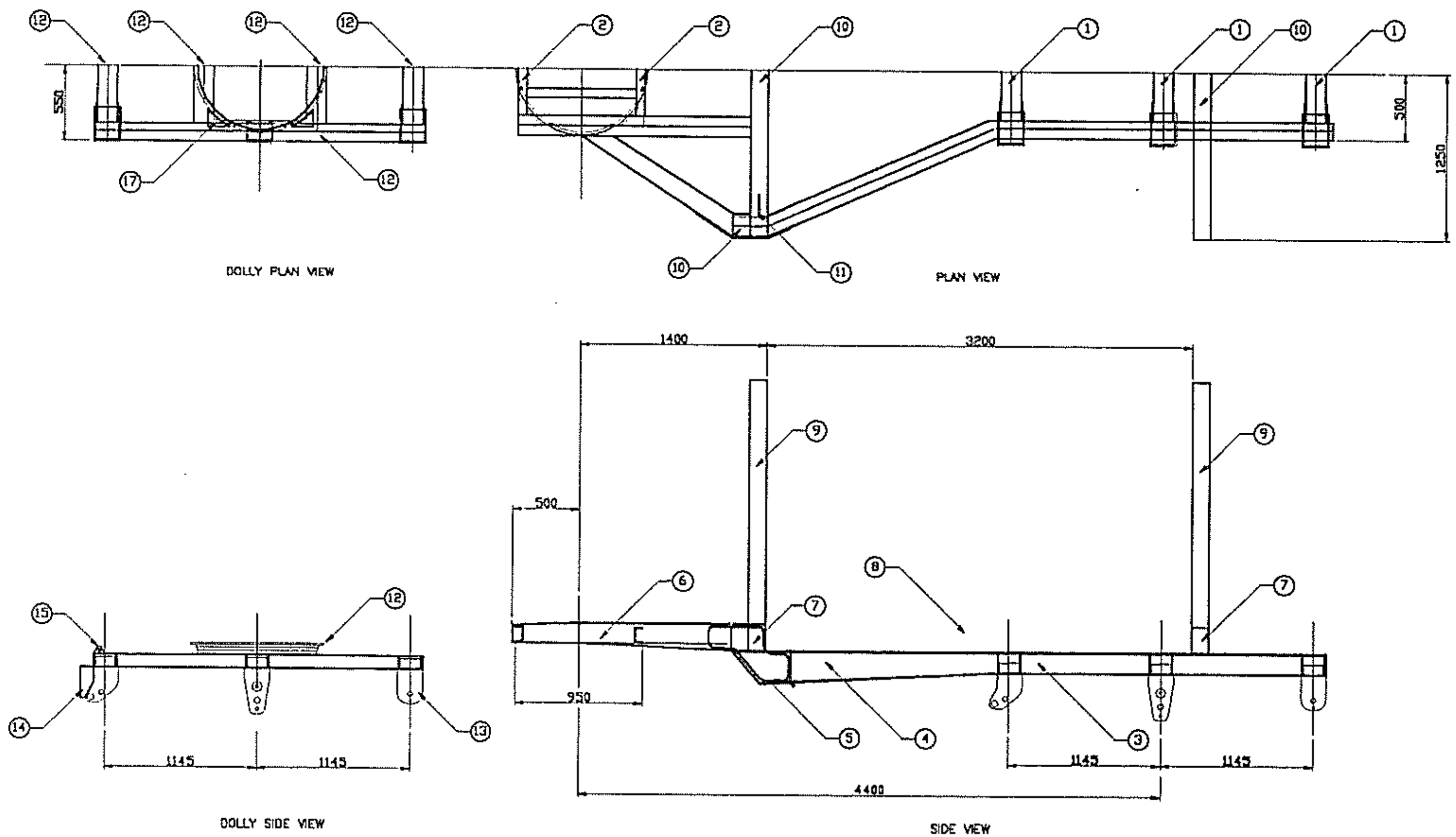
# LAYOUT DRAWINGS FOR 3 AXLE PERIMETER FRAME TRAILER

CLIENT:LIRO

560415

Sheet: 01

| Ref: 10000 | Drawn: 5/2/99 | Issue: A | Chkd: |
|---|---|---|---|
| | Date: 5/2/99 | Scale: 1:50 | Date: |




| ITEM | QTY | MATERIAL | DESCRIPTION | DRG No. |
|---|---|---|---|---|
| 18 | | | | |
| 17 | 4 | Ex 10mm | GUSSET | |
| 16 | | | DRAWBAR SPRING MOUNT | |
| 15 | 1 | | DRAWBAR HINGE KIT | |
| 14 | 2 | | HANGER | |
| 13 | 1 | | TURNTABLE | |
| 12 | | 100mm deep | DOLLY I-BEAM | |
| 11 | 2 | Ex 10mm | GUSSET | |
| 10 | 2 | 200x130x6 RHS | BOLSTERS | |

| ITEM | QTY | MATERIAL | DESCRIPTION | DRG No. |
|---|---|---|---|---|
| 9 | | 200 x 130 x 6 RHS | STANCHION | |
| 8 | 4 | 60 x 10 Flat | STRAP | |
| 7 | | Ex 10mm | STRAP | |
| 6 | | 150 UC 23.4 | CHASSIS | |
| 5 | 4 | Ex 10 mm | GUSSET | |
| 4 | 2 | I BEAM | TAPERED CHASSIS BEAM | |
| 3 | 2 | 160 deep | CHASSIS I-BEAM | |
| 2 | 2 | 127 x 65 RSC | CROSS MEMBER | |
| 1 | 3 | 150 x 100 x 9 | CROSS MEMBER | |

| ISSUE | DATE | CHANGES MADE | BY |
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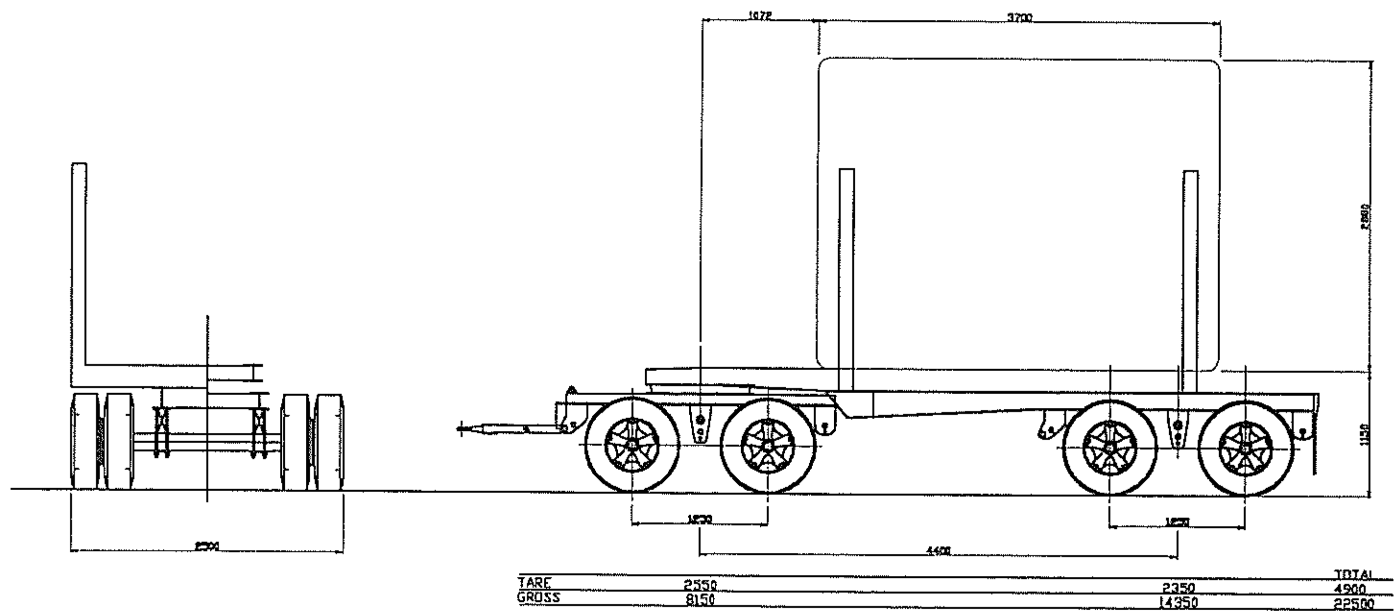
# CHASSIS DETAILS - 4 AXLE PERIMETER FRAME LOGGING TRAILER

CLIENT: LIRO

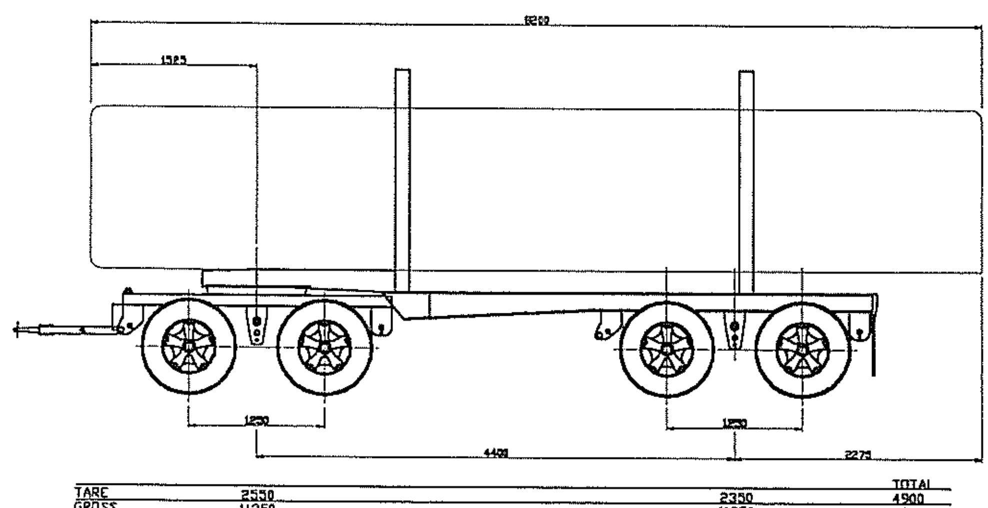
520170

Sheet: 02

| | | | |
|---|---|---|---|
| Ref: 10000 | Drawn: | Issue: A | Chkd: |
| | Date: 4/2/99 | Scale: 1:40 | Date: |




| LOG LENGTH | TRAILER PAYLOAD | TRAILER CoG |
|---|---|---|
| 3.7 | 17600 | 2.16 |
| 4.1 | 17600 | 2.05 |
| 5.8 | 17600 | 1.80 |
| 7.4 | 17600 | 1.68 |
| 8.2 | 17600 | 1.62 |

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# LAYOUT DRAWINGS FOR 4 AXLE PERIMETER FRAME TRAILER

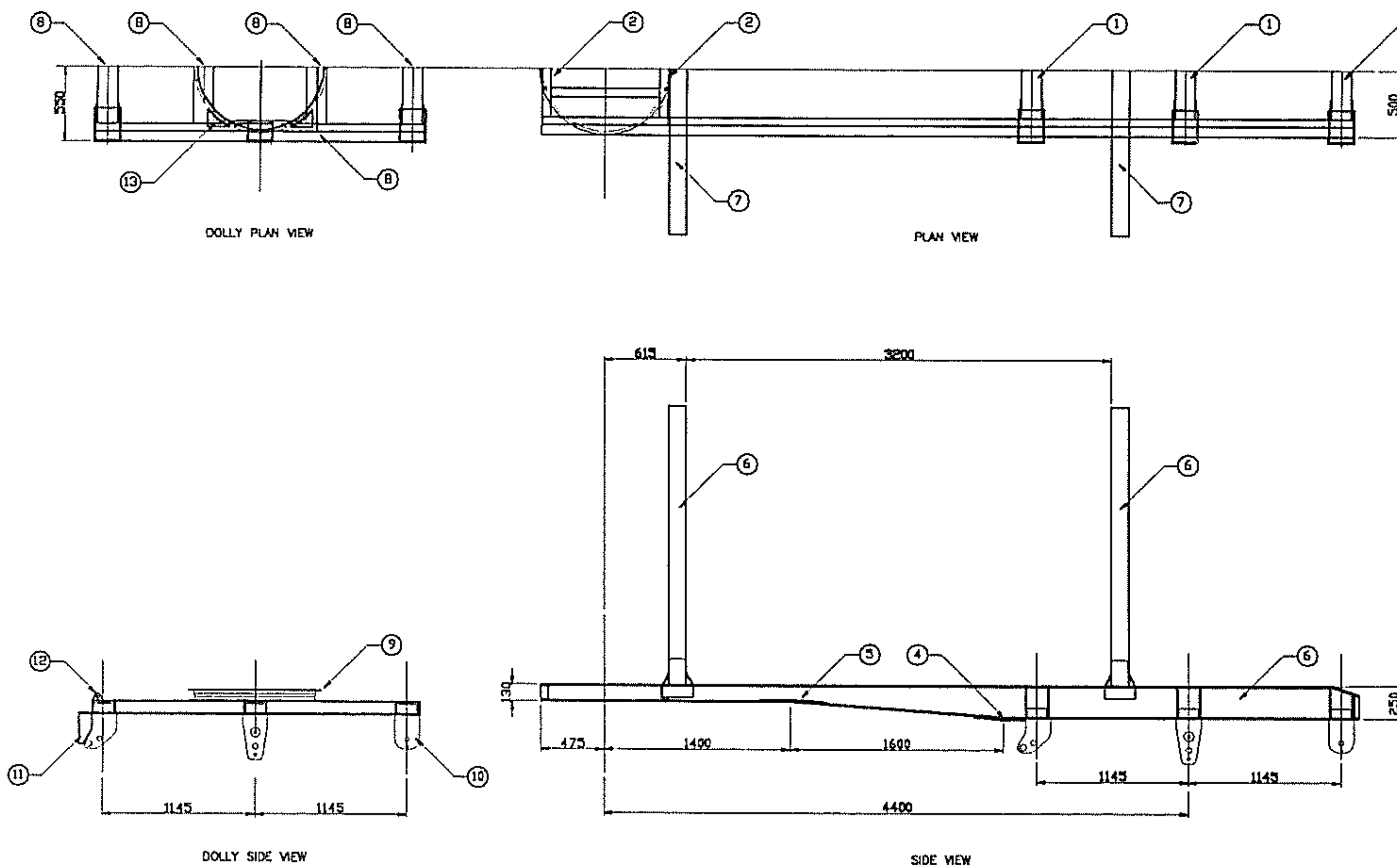
CLIENT:LIRO

560415

Sheet: 02

Drawn: 4/2/1999 | Issue: A | Chkd:

Ref: 10000 | Date: 4/2/1999 | Scale: 1:50 | Date:




| ITEM | QTY | MATERIAL | DESCRIPTION | DRG No. |
|---|---|---|---|---|
| 18 | | | | |
| 17 | | | | |
| 16 | | | | |
| 15 | | | | |
| 14 | | | | |
| 13 | 4 | Ex 10mm | GUSSET | |
| 12 | | | DRAWBAR SPRING MOUNT | |
| 11 | 1 | | DRAWBAR HINGE KIT | |
| 10 | 2 | | HANGER | |

| ITEM | QTY | MATERIAL | DESCRIPTION | DRG No. |
|---|---|---|---|---|
| 9 | 1 | | TURNTABLE | |
| 8 | | 100 mm deep | DOLLY I-BEAM | |
| 7 | 2 | 200 x 130 x 6 RHS | BOLSTERS | |
| 6 | 4 | 200 x 130 x 6 RHS | STANCHION | |
| 5 | 4 | 60 x 10 Flat | GUSSET | |
| 4 | 2 | 150 x 10 Flat | STRAP | |
| 3 | 2 | I BEAM | VARIED DEPTH CHASSIS I-BEAM | |
| 2 | 2 | 127 x 65 RSC | CROSS MEMBER | |
| 1 | 3 | 150 x 100 x 9 | CROSS MEMBER | |

| ISSUE | DATE | CHANGES MADE | BY |
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| C | | | |
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# CHASSIS DETAILS - 4 AXLE LOWERED EXISTING FRAME

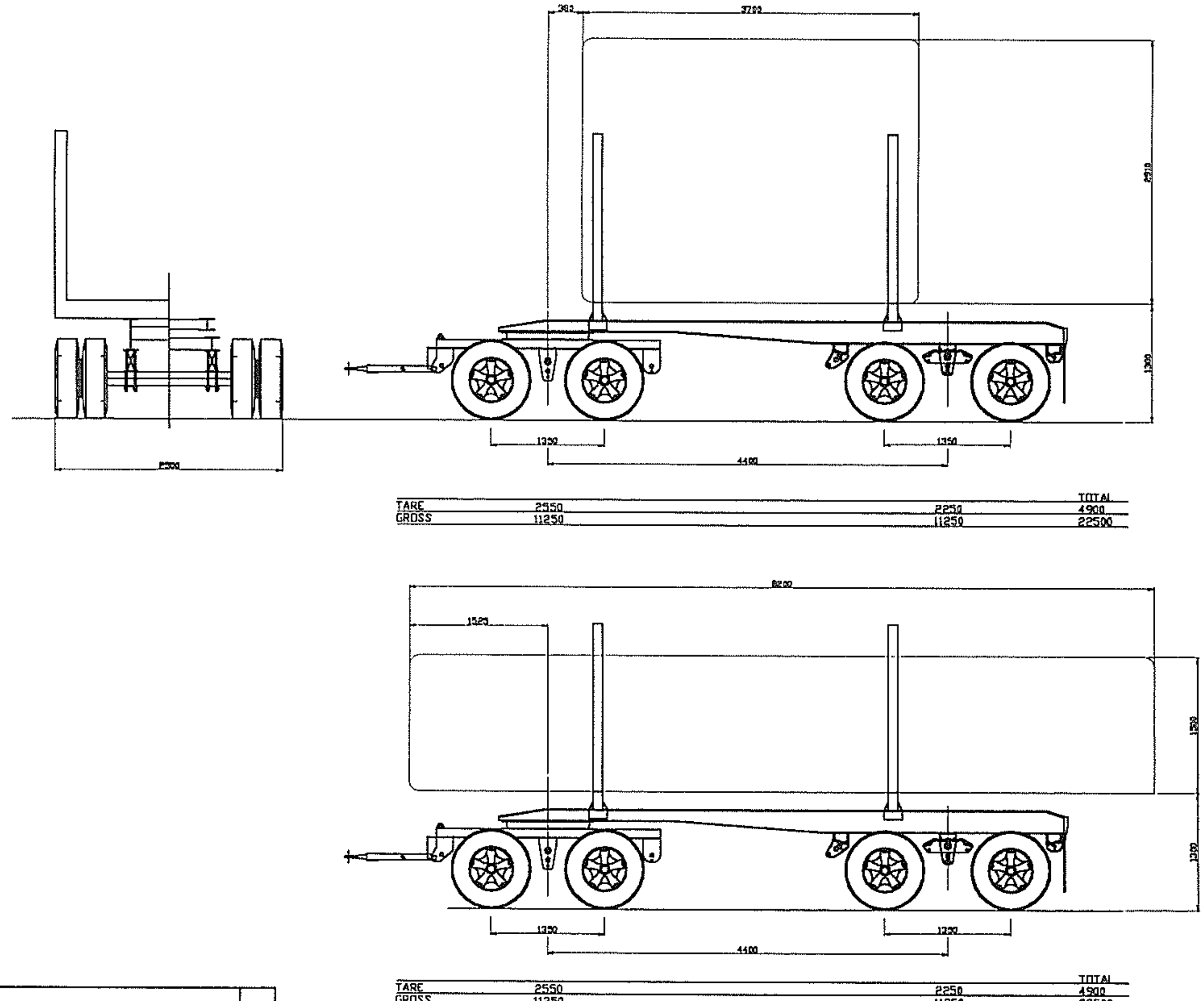
CLIENT:LIRO

520171

Sheet: 03

Drawn: 4/2/1999 | Issue: A | Chkd:
Ref: 10000 | Date: 4/2/1999 | Scale: 1:40 | Date:

| LOG LENGTH | TRAILER | |
|---|---|---|
| | PAYLOAD | CoG |
| 3.7 | 17750 | 2.30 |
| 4.1 | 17750 | 2.18 |
| 5.8 | 17750 | 1.93 |
| 7.4 | 17750 | 1.81 |
| 8.2 | 17750 | 1.75 |




| ISSUE | DATE | CHANGES MADE | BY |
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# LAYOUT DRAWINGS FOR LOWERED EXISTING LOGGING TRAILER

CLIENT:LIRO

560415

Sheet: 03

Drawn: 4/2/99 | Issue: A | Chkd:

Ref: 10000 | Date: 4/2/99 | Scale: 1:50 | Date: